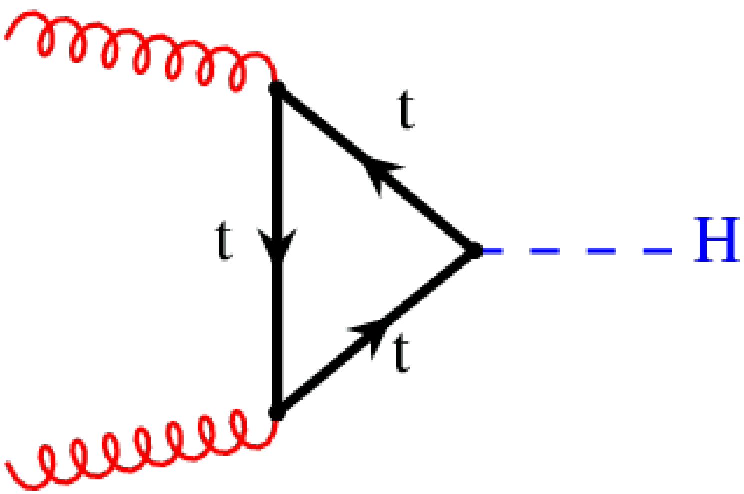
Approval of H → WW → lnujj



Nural Akchurin[1], Jake Anderson[2], Chayanit Asawatangtrakuldee[11], Andrea Benaglia[3], Andrew Beretvas[2], Jeffrey Berryhill[2], Pushpa Bhat[2], Sarah Boutle[4], Chris Clarke[5], Fabio Colombo[3], Analu Custodio[10], Jordan Damgov[1], Leonardo Di Matteo[3], Phil Dudero[1], Ricardo Eusebi[6], James Faulkner[1], Pietro Govoni[12], Dan Green[2], Joey Goodell[4], Robert Harr[5], Pratima Jindal[13], Ajay Kumar[7], Kevin Lannon[9], Sung-Won Lee[1], Qiang Li[11], Shuai Liu[11], Wuming Luo[9], Yajun Mao[11], Kalanand Mishra[2], Md. Naimuddin[7], Chris Neu[4], Ilya Osipenkov[6], Alexx Perloff[6], Kirti Ranjan[7], Sasha Sakharov[5], Ram K Shivpuri[7], Kevin Siehl[5], Andre Sznajder[10], Patricia Teles[10], Nhan V. Tran[2], Zijun Xu[11], Weimin Wu[2], John Wood[4], Fan Yang[2], Francisco Yumiceva[2], and Wei Zou[11]

[1] Texas Tech University, Lubbock, Texas, USA
[2] Fermi National Accelerator Laboratory, Batavia, Illinois, USA
[3] Milano-Bicocca University and INFN, Milan, Italy
[4] University of Virginia, Charlottesville, Virginia, USA
[5] Wayne State University, Detroit, Michigan, USA
[6] Texas A&M University, College Station, Texas, USA
[7] Delhi University, Delhi, India
[8] University of Nebraska at Lincoln, Nebraska, USA
[9] University of Notre Dame, Notre Dame, Indiana, USA
[10] Universidade do Estado do Rio de Janeiro (UERJ), Brazil
[11] Peking University, China
[12] CERN
[13] Princeton Unversity, New Jersey, USA

AJAY KUMAR

University of Delhi

On behalf of The Semileptonic team

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2. Sunil Somalwar
3. Roberto Castello
4. Ezio Torasso

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Jim Olsen

Marco Pieri

And the HWW sub-group conveners:

1. Pietro Govoni
2. Xavier Janssen

Documentation

CMS PAS HIG-13-027

DRAFT
CMS Physics Analysis Summary
The content of this note is intended for CMS internal use and distribution only

2014/06/09
Head Id: 151429
Archive Id: 245395P
Archive Date: 2012/10/09
Archive Tag: trunk

Search for a Standard Model-like Higgs boson in the $H \to WW \to \ell\nu jj$ decay channel in pp collisions at the LHC

The CMS Collaboration

Abstract

A search for a standard model-like Higgs boson decaying to two W bosons with the subsequent decay to a final state containing one lepton, one neutrino, and two jets is presented. The results are based on a data sample corresponding to an integrated luminosity of 19.3 fb^{-1} of proton-proton collisions at $\sqrt{s} = 8$ TeV and 5 fb^{-1} at $\sqrt{s} = 7$ TeV collected with the CMS detector at the CERN LHC. Selections to discriminate between the signal and background events are based on kinematic and topological quantities including the angular spin correlations between the decay products. A standard model-like Higgs boson is excluded in the mass ranges 170–180 GeV and 230–545 GeV at 95% confidence level, while the median expected exclusion ranges are 170–180 GeV and 255–565 GeV. The results are also interpreted within the framework of an effective theory that predicts the existence of two Higgs-like scalar particles, one with $M \sim 126$ GeV, and one that is heavier, which together accomplish the unitarization of the WW scattering cross section.

This box is only visible in draft mode. Please make sure the values below make sense.

PDFAuthor:	CMS collaboration, lvjj team
PDFTitle:	Search for the Standard Model Higgs boson in the H to WW to lnujj decay channel in pp collisions at the LHC
PDFSubject:	CMS
PDFKeywords:	CMS, physics, Higgs, WW, semi-leptonic, lnujj

Please also verify that the abstract does not use any user defined symbols

Cadi/PAS: **HIG-13-027**

Hypernews:

https://hypernews.cern.ch/HyperNews/CMS/get/HIG-13-027.html

Analysis Note: **AN-2012/463**

Review Q & A:

https://twiki.cern.ch/twiki/bin/viewauth/CMS/HIG-13-027-ARC

Last Public Result HCP 2012: **HIG-12-046**

Results to be included in HIG-13-031

Outline

Introduction

(Intro, Data, Simulation, Event-selection, Control plots)

MVA optimization

(Kinematics, Training, Discriminant)

Likelihood analysis

(Background estimation, Fitting)

Results

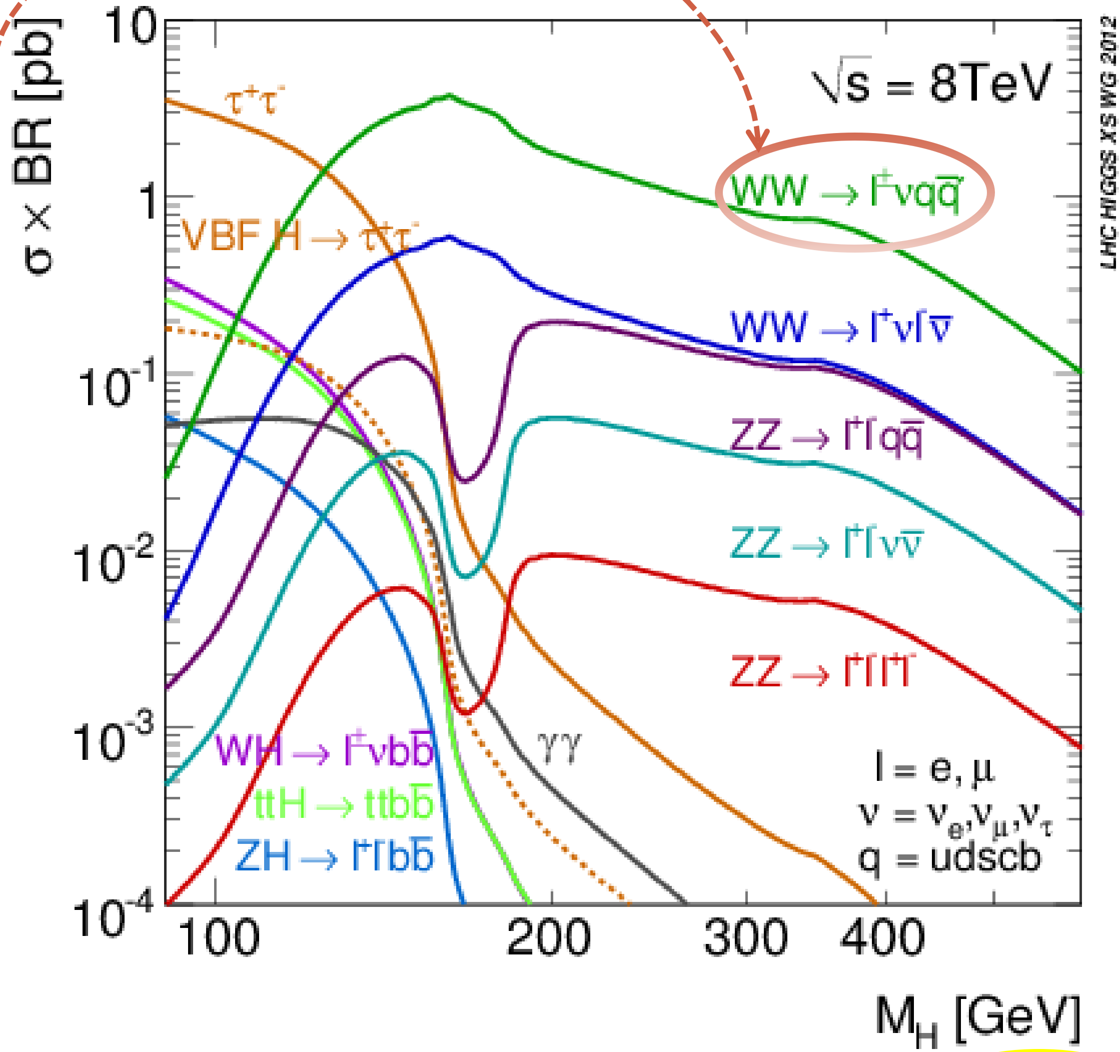
(Unblinded results, Limit, BSM limit)

Introduction

SM Higgs discovered at 125 GeV.

We search for additional higgs state using H→WW→lvjj channel because:

- ➢largest BR x σ over most of the mass range.
- ➢ using W mass constraint, the decay is sufficiently reconstructed to produce a mass peak.
- ➢Principal drawback is huge W+jets background
  We use data-driven technique to control and understand this.



Introduction

Data & Trigger

Single lepton triggers with $P_T > 24$ (27) muons (electrons).

Dataset name	*Run range*
/SingleMu/Run2012A-13Jul2012-v1/AOD	190456-193621
/SingleElectron/Run2012A-13Jul2012-v1/AOD	
/SingleMu/Run2012A-recover-06Aug2012-v1/AOD	190782-190949
/SingleElectron/Run2012A-recover-06Aug2012-v1/AOD	
/SingleMu/Run2012B-13Jul2012-v1/AOD	193833-196531
/SingleElectron/Run2012B-13Jul2012-v1/AOD	
/SingleMu/Run2012C-24Aug2012-v1/AOD	198022-198913
/SingleElectron/Run2012C-24Aug2012-v1/AOD	
/SingleMu/Run2012C-PromptReco-v2/AOD	198934-203746
/SingleElectron/Run2012C-PromptReco-v2/AOD	
/SingleMu/Run2012D-PromptReco-v1/AOD	203894-208686
/SingleElectron/Run2012D-PromptReco-v1/AOD	

This correspond to Total Integrated Luminosity : 19.3(19.2) fb^{-1} muon(electron)

Simulation samples

Signal samples:

POWHEG-BOX , reweighted appropriately.

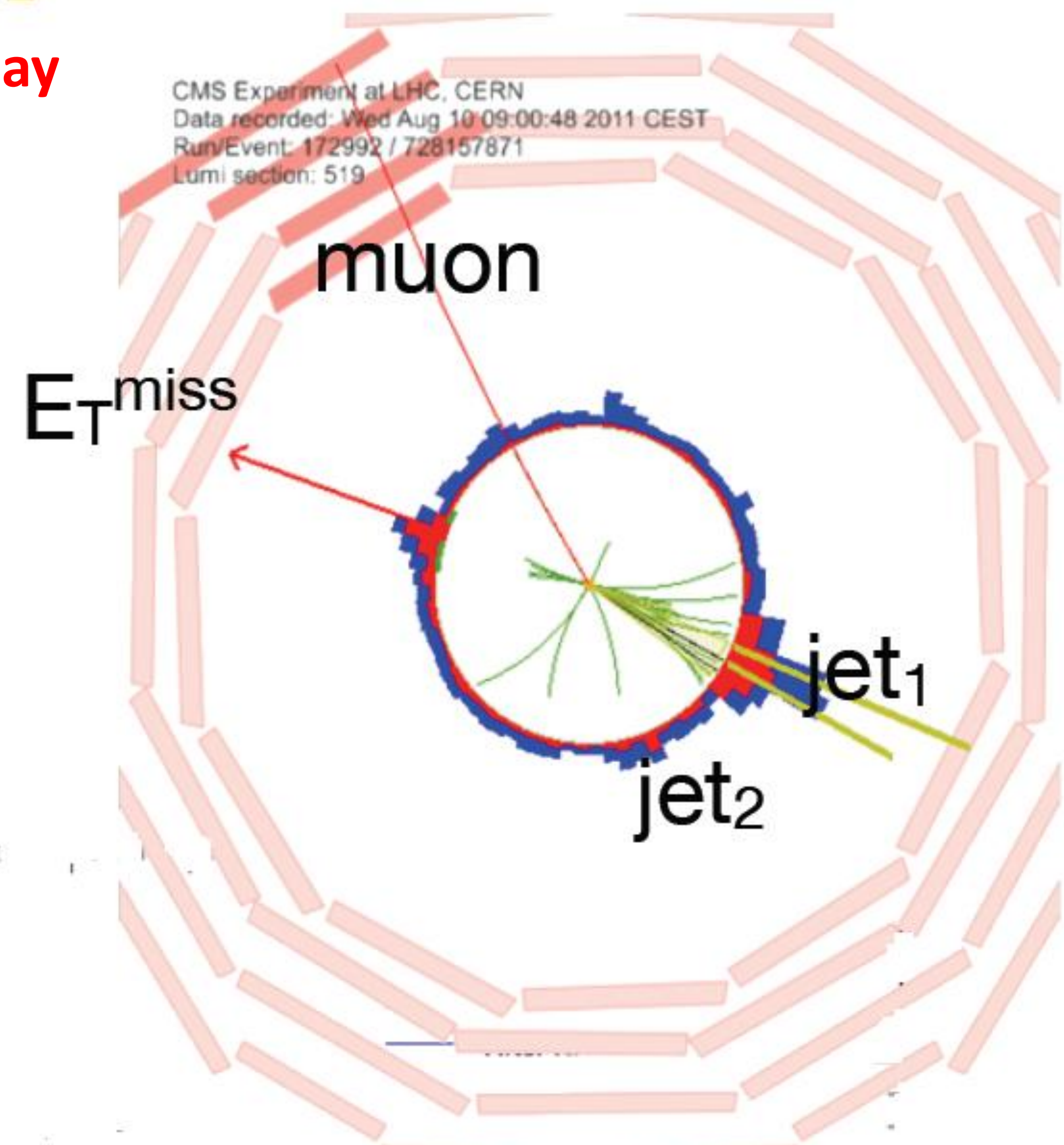
/GluGluToHToWWToLAndTauNuQQ_M-*

/VBF_HToWWToLAndTauNuQQ_M-*

Backgrounds:

/W2JetsToLNu_TuneZ2Star_8TeV-madgraph/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/W3JetsToLNu_TuneZ2Star_8TeV-madgraph/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/W4JetsToLNu_TuneZ2Star_8TeV-madgraph/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/WW_TuneZ2star_8TeV_pythia6_tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/WZ_TuneZ2star_8TeV_pythia6_tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/TTJets_MassiveBinDECAY_TuneZ2star_8TeV-madgraph-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/DYJetsToLL_M-50_TuneZ2Star_8TeV-madgraph-tarball/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/T_t-channel_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/T_s-channel_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/T_tW-channel-DR_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/Tbar_t-channel_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/Tbar_tW-channel-DR_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM
/Tbar_s-channel_TuneZ2star_8TeV-powheg-tauola/Summer12_DR53X-PU_S10_START53_V7A-v1/AODSIM

Event Display



Introduction

Event selections

❖ Muons (electrons)

P_T > 25 (30) GeV

$|\eta|$ < 2.1 (2.5)

Isolation:

relIso < 0.14 (0.105-0.150)

ID:

(MVA electron id WP80)

veto events with a 2nd loose lepton

$\Delta\Phi$(l,jet) > 0.4 (0.8)

❖ Jets (PFAK5)

- P_T > 30 GeV
- $|\eta|$ < 2.4
- Anti-b-tag on all jets with P_T >30GeV
- No criteria on additional jet activity (i.e. inclusive)

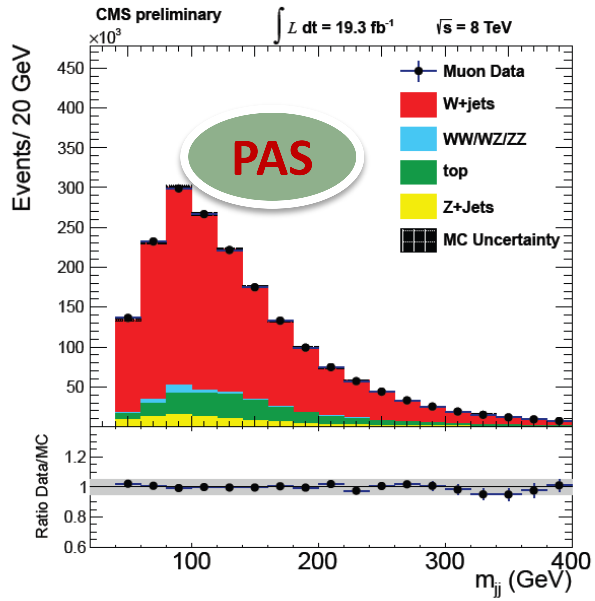
❖ Leptonic W

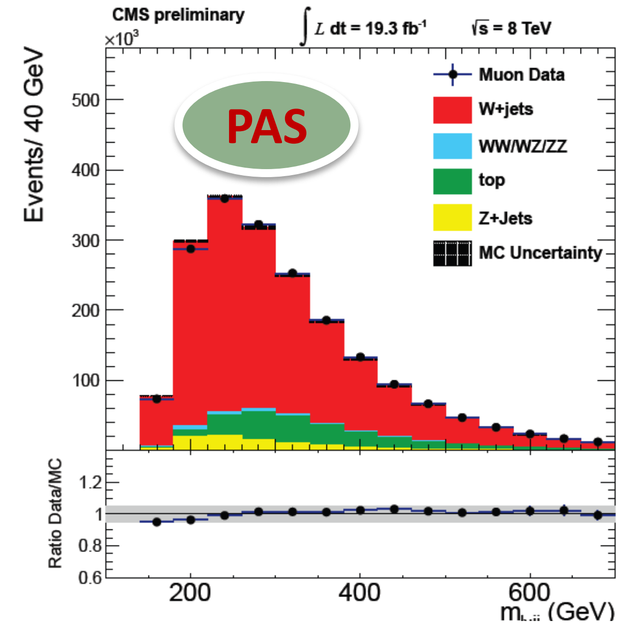
- MET > 25 (30) GeV
- m^W_T > 30 GeV

Pile up reweighting, Trigger, reconstruction and identification efficiency applied.

Data/MC Comparisons

μ





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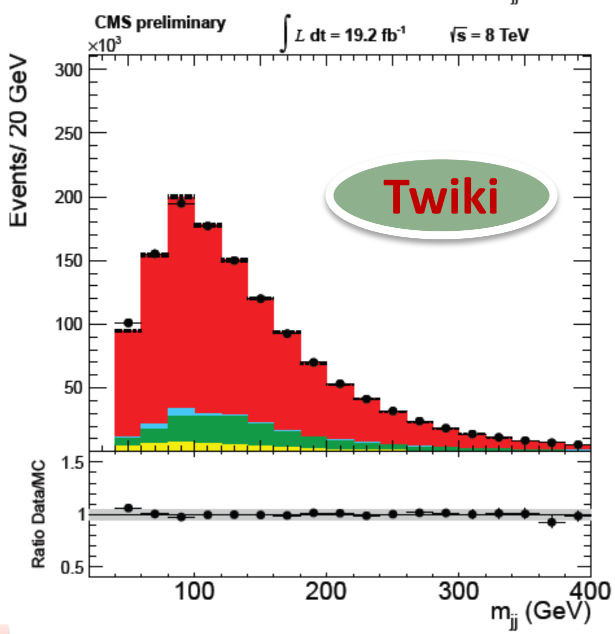
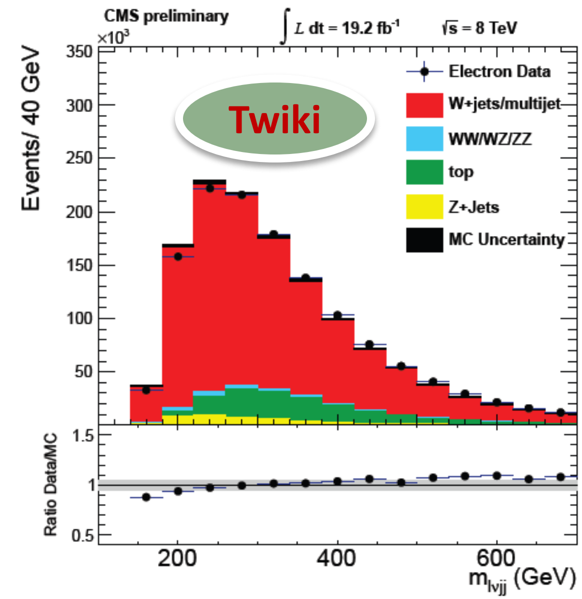
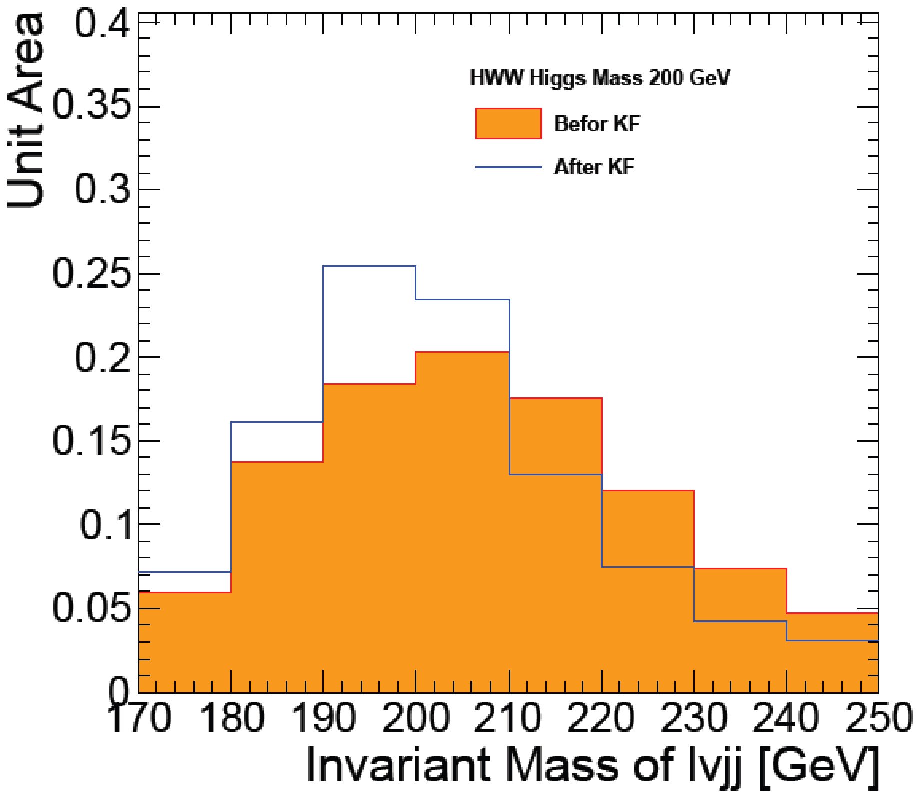
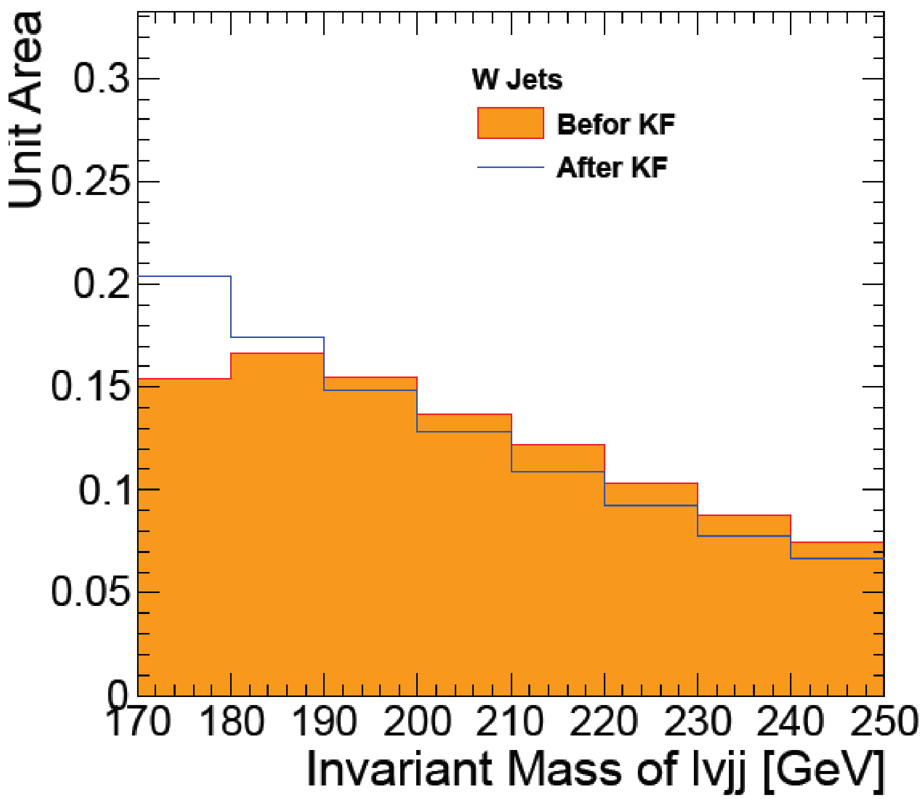




Kinematic fit

We use kinematic fit to enhance four body mass (i.e. m_{lvjj}) resolution and remove correlation between m_{jj} and m_{lvjj}.





MVA optimization

Higgs boson decay kinematics is fully described by →

{$m_{l\nu jj}$, m_{jj}, $\cos(\theta^*)$, φ_1, φ, $\cos(\theta_1)$, $\cos(\theta_2)$}

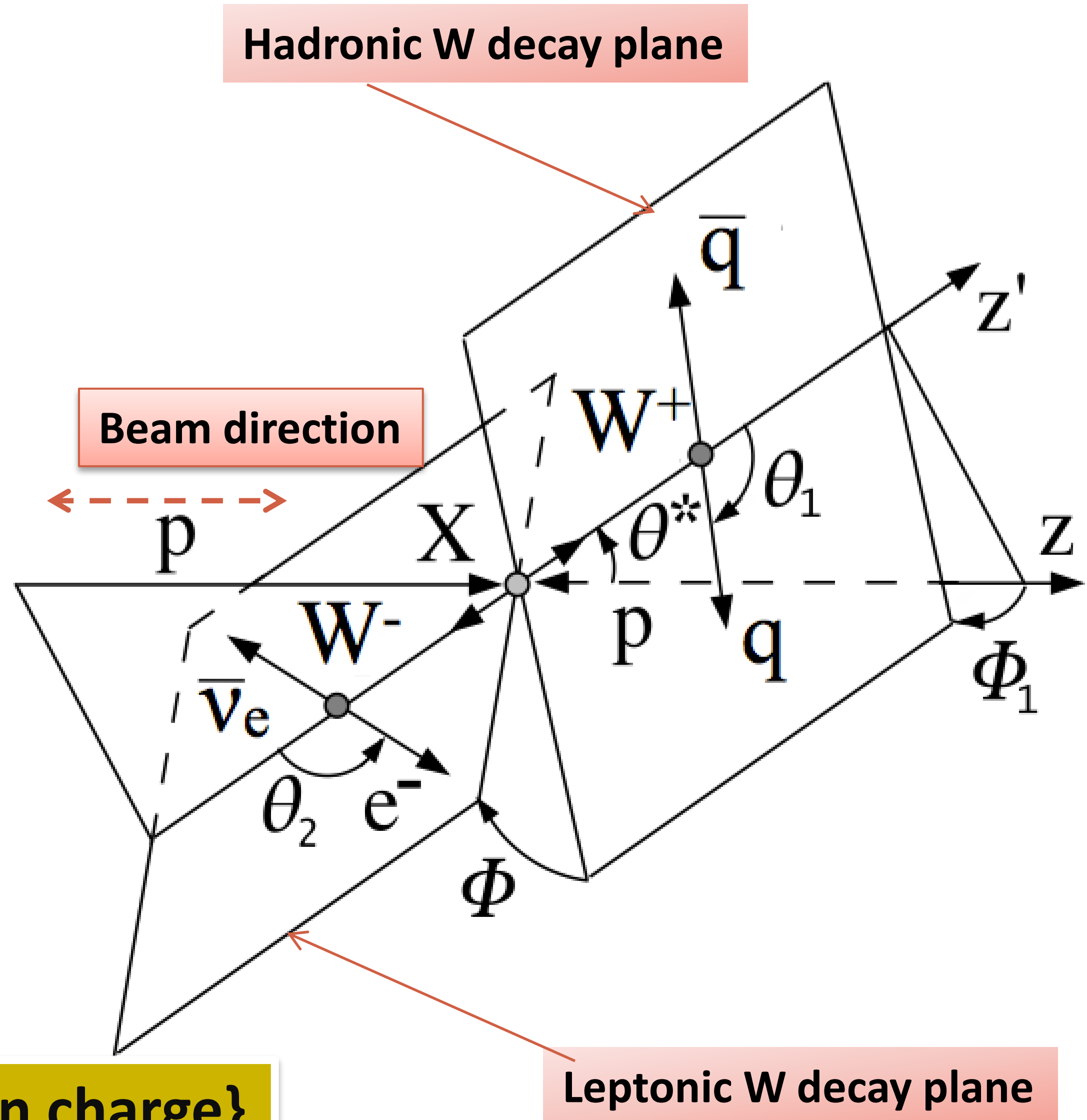
- $m_{l\nu jj}$ is the variable we use to extract limit, so it is not included

- m_{jj} used to estimate background normalization, so it is not included

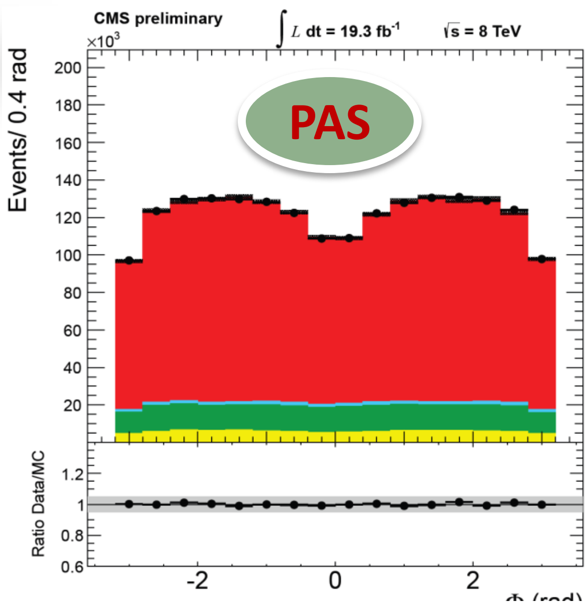
• Lepton charge is a good variable since signal is charge-symmetric, while W+jets is not

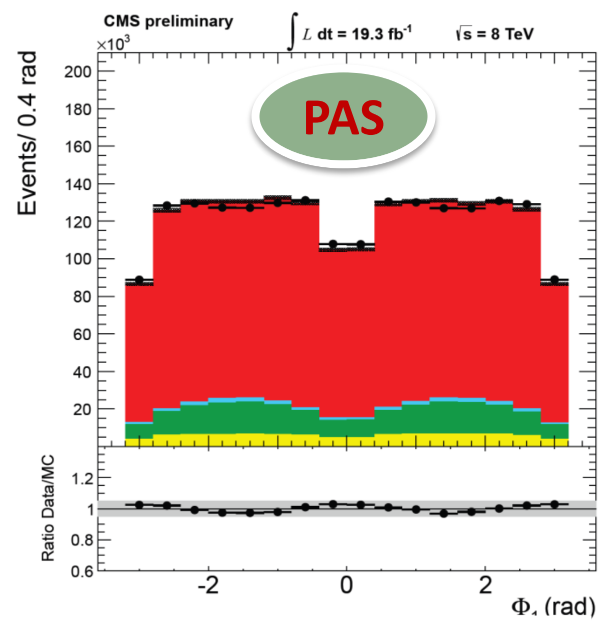
So, the inputs are:

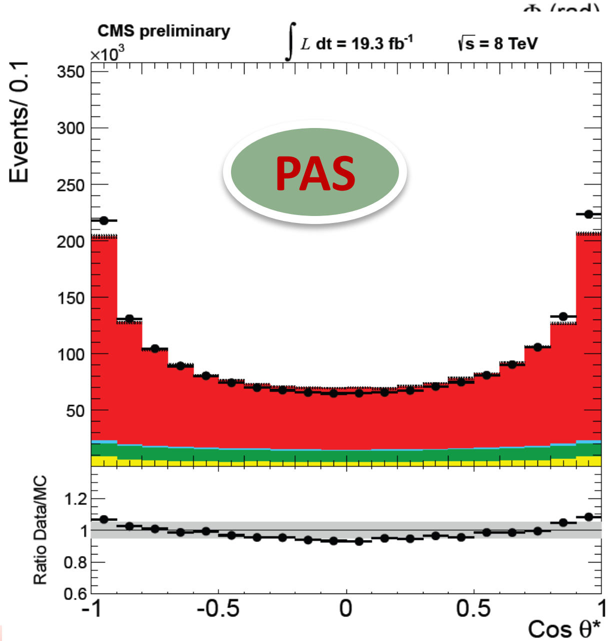
{ $\cos(\theta_2)$, $\cos(\theta^*)$, φ, φ_1, lepton charge}

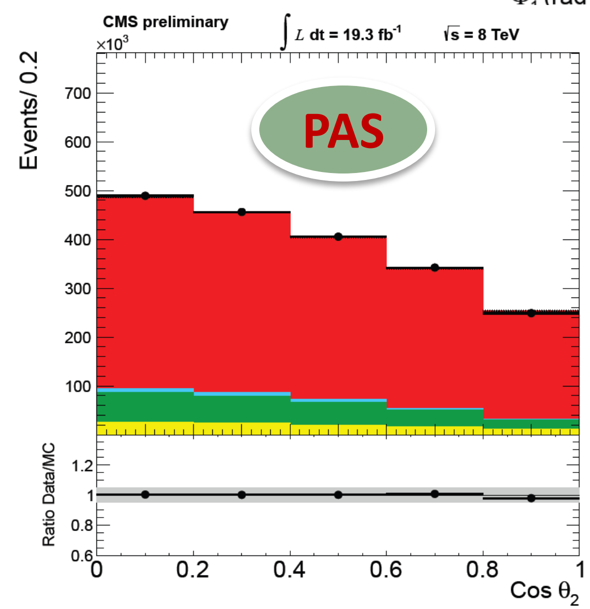


input variables data/MC comparisons

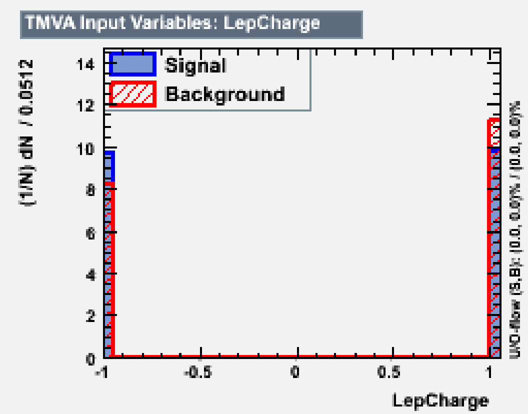


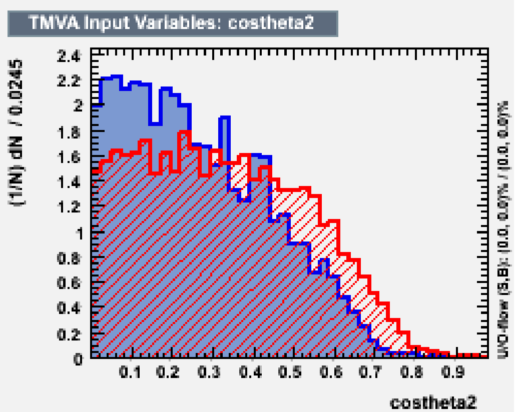


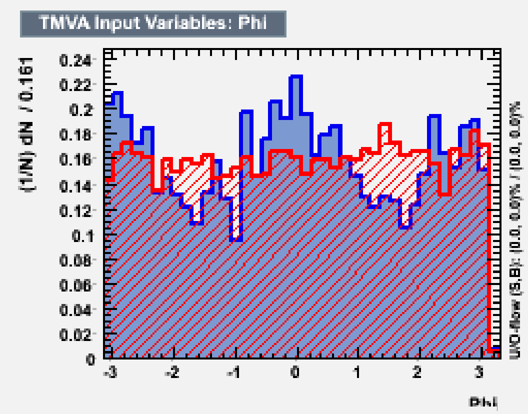


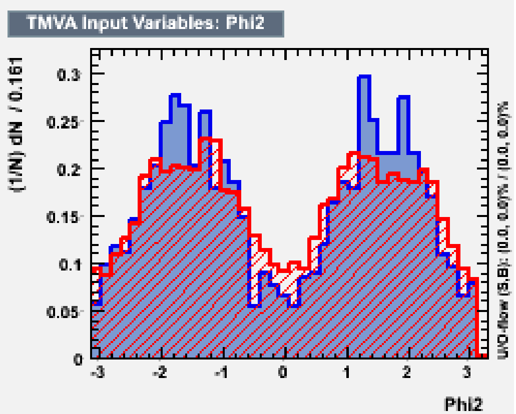


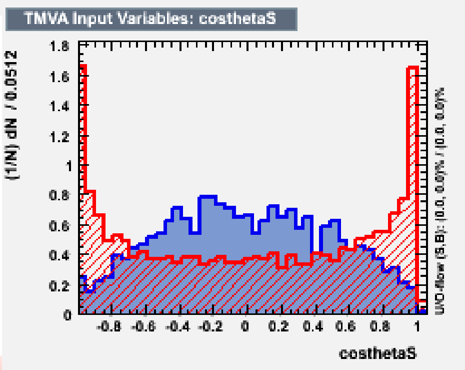
MVA Training details



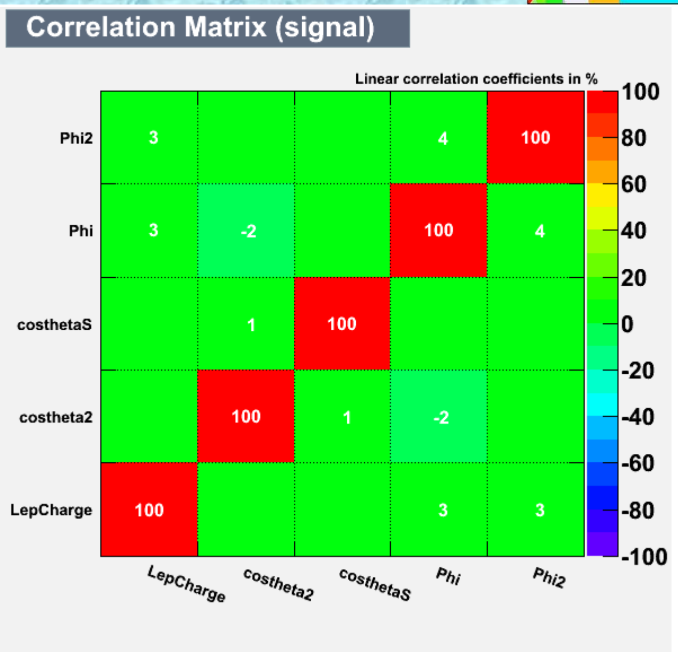


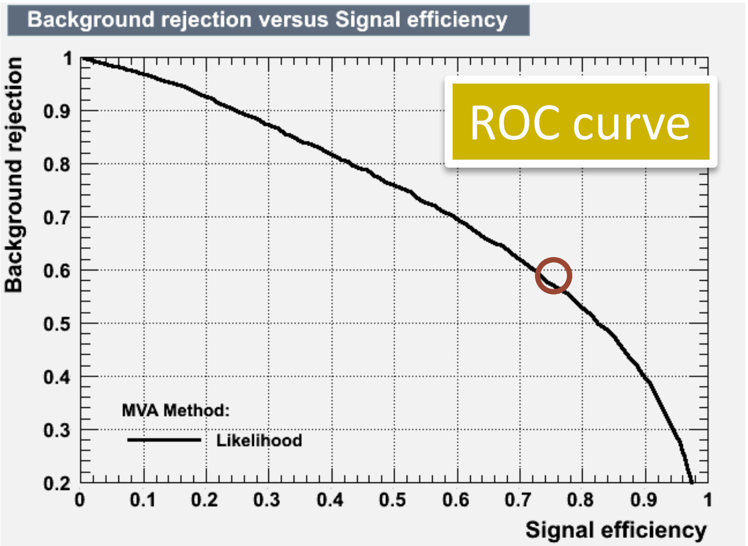




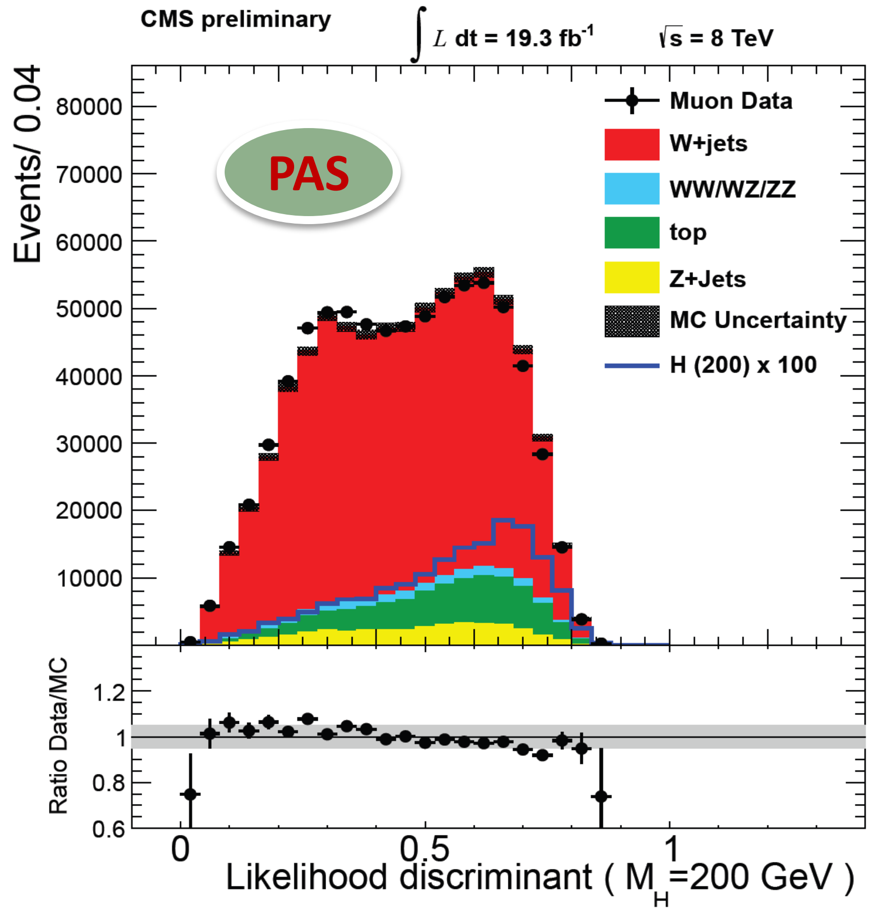


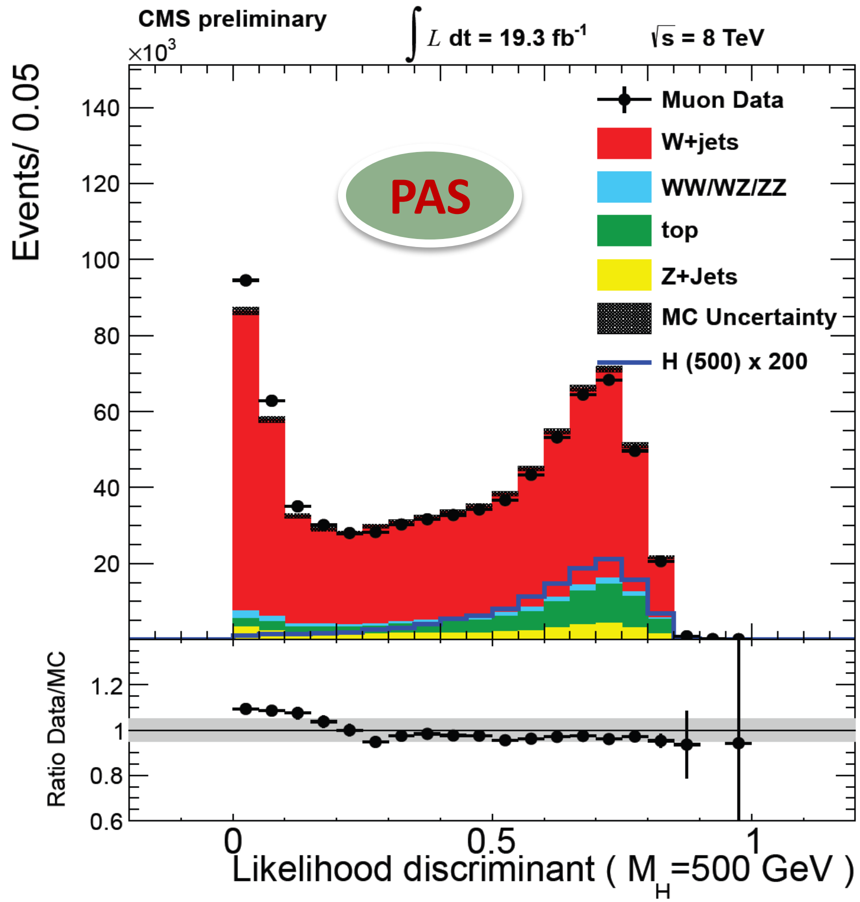
For higgs mass 250Gev, Muon Channel, Representative Plots.





Example of likelihood output





TMVA optimization

Optimizing the MVA selection

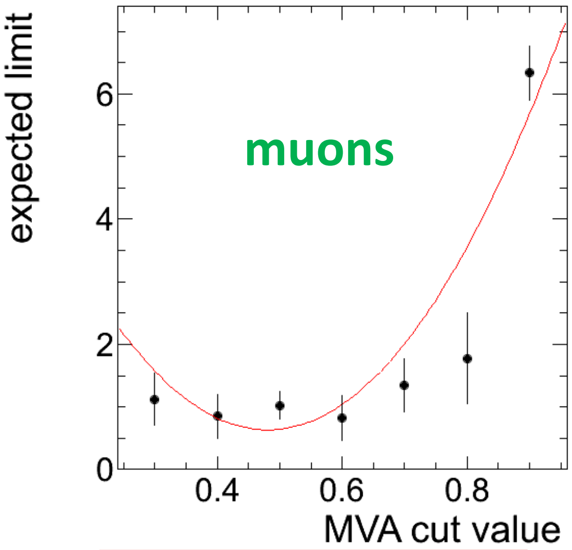
❖scan MVA cut values for best expected limit

❖**Approx. optimal around 0.5 for masses up to 500 GeV.**

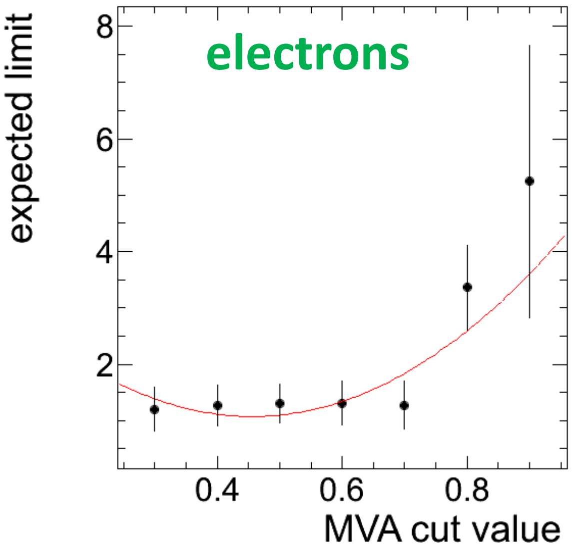
& 0.6 for 550 and 600

❖**the minimum is rather broad**

❖**By construction, 0.5 natural separation between signal-like and background-like.**



Higgs mass 250GeV



Likelihood analysis

Likelihood analysis

After all selections are applied:

Simultaneous fit and limit extraction using statistical combination tools used cms-wide,

1st fit: an unbinned maximum likelihood fit to m_{jj} distribution in data side bands:

--Background yields

2nd fit: binned maximum likelihood fit to four body mass with simultaneous exclusion limit extraction

--four body shape, limits

Likelihood analysis--The m_{jj} fit in sidebands

Data-driven background estimation

- ❖**Unbinned maximum likelihood fit to the data.**
- ❖**m_{jj} excluded (66-98)**
- ❖**Side band dominated by W+Jets**

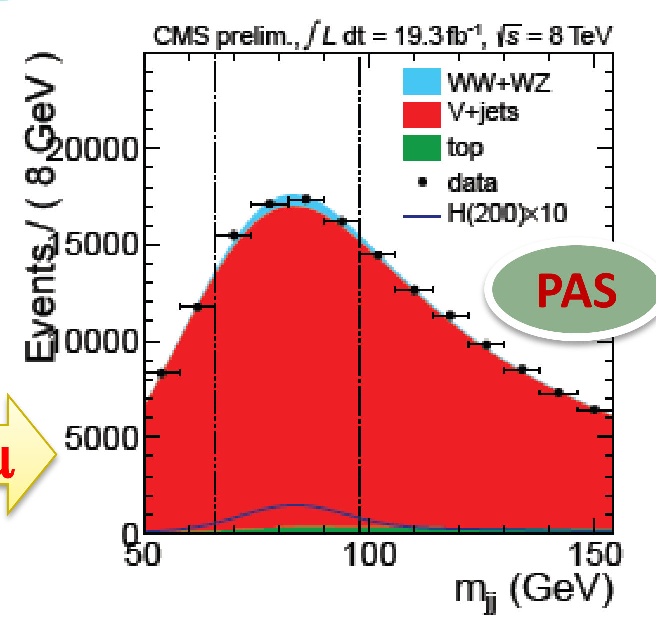
Shape:

- ❖ Diboson and top components shapes fixed to the expectations from MC.
- ❖ W+jets shape parameters loosely constrained.

Yield:

- ❖W+jets component yield, free parameter, others constrained to theory uncertainties
- ❖ **The W+jets yield and its uncertainty are propagated to the next step in the analysis.**

μ



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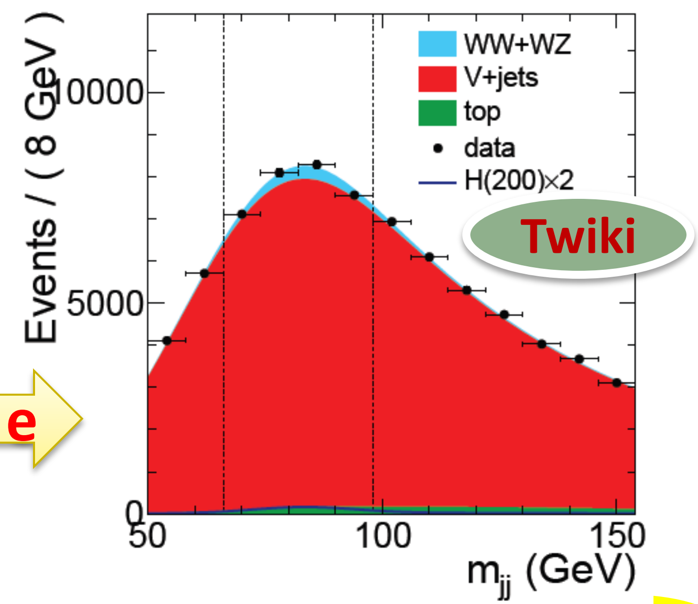
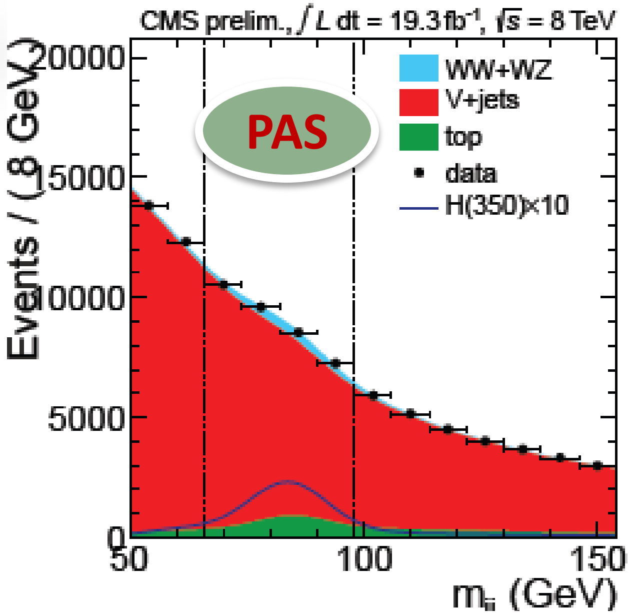
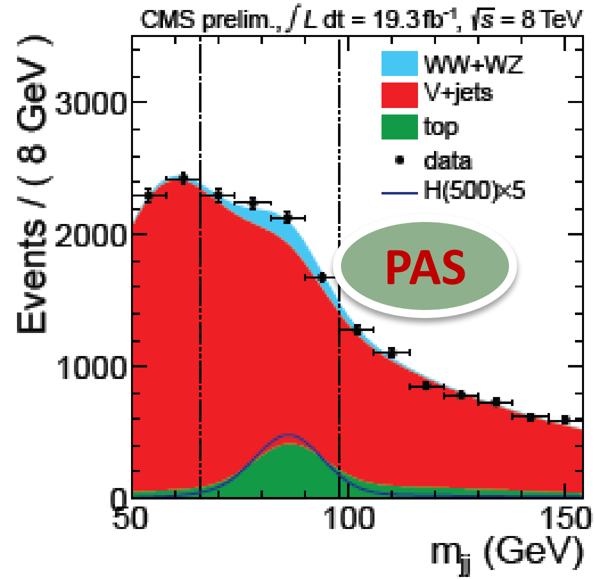


Likelihood analysis--The m_{jj} fit in sidebands

μ





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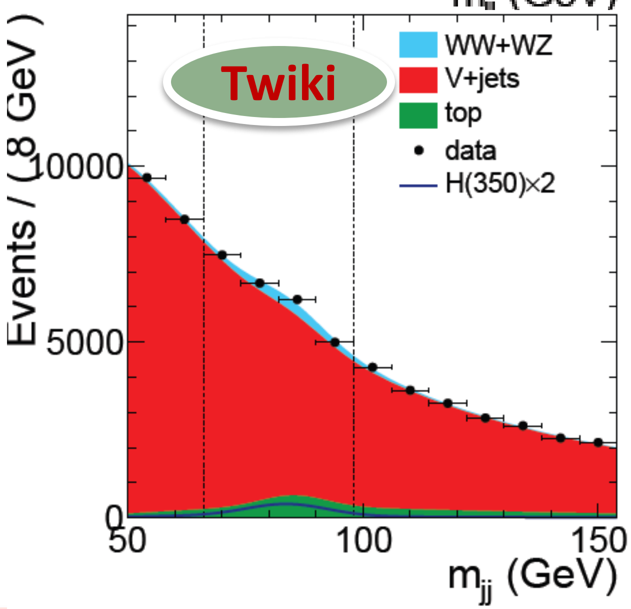
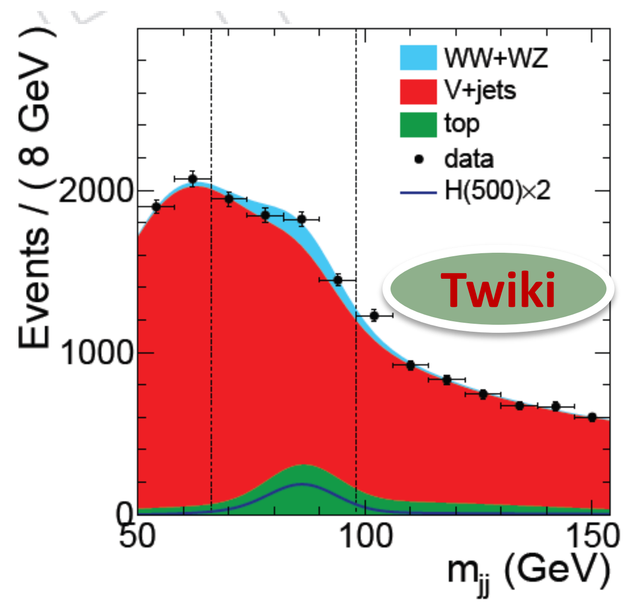


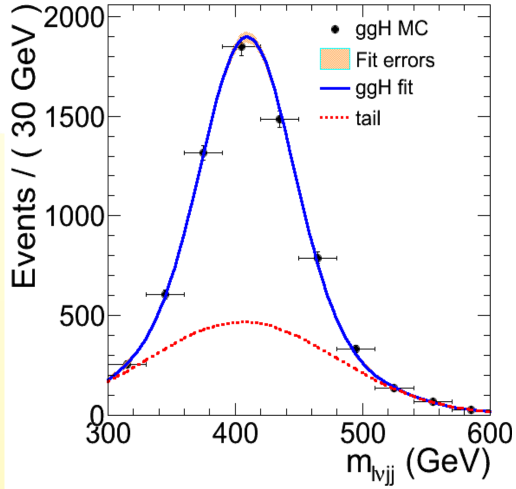


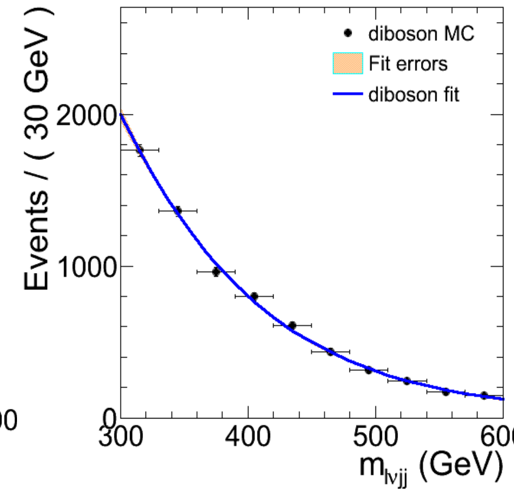
Likelihood analysis-- four body mass shapes, fit

Likelihood analysis-- four body mass shapes

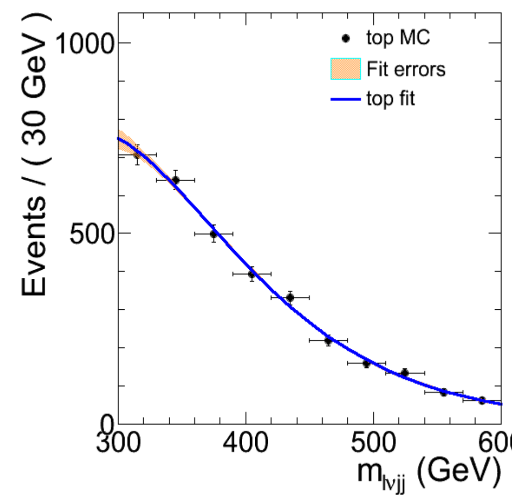
m_{lvjj} model determination

- ❖ Functional form for Diboson, top & signal determined from MC
- ❖ Functional form for V+jets determined by iterative procedure:
  1. Fit to MC sideband and signal regions, and data sideband region
  2. Fit quality determines success
  3. Failure -> try new model with more DOF
- ❖ All backgrounds have generally monotonically falling spectra.





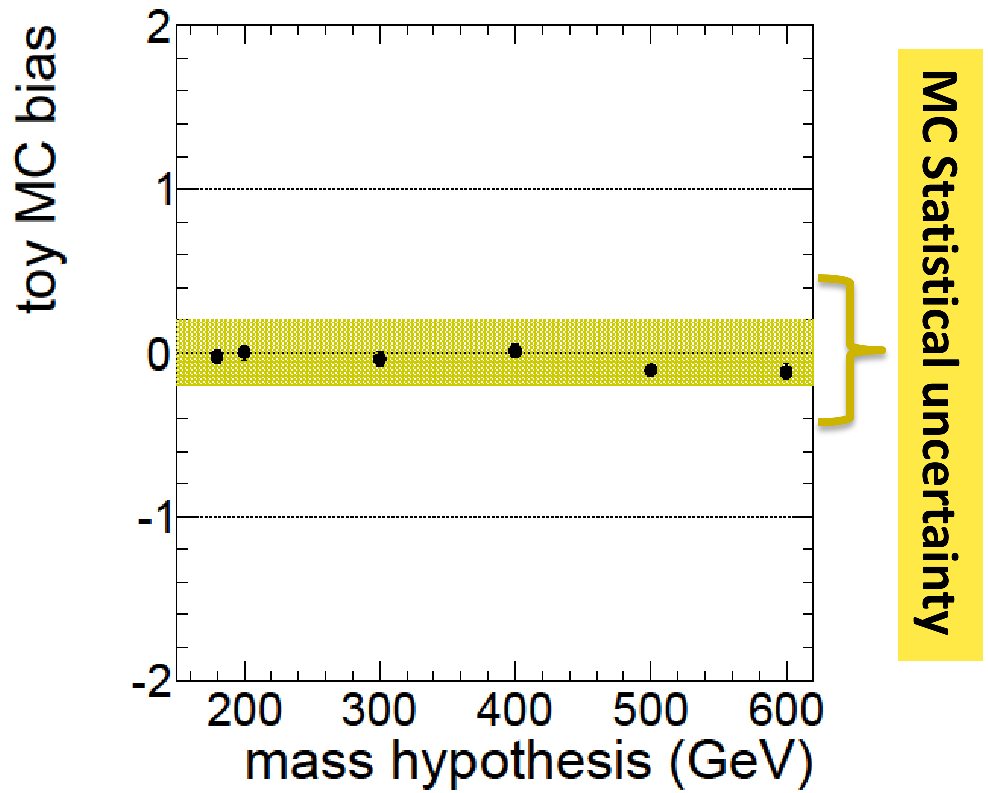
Fit to MC to smooth the shape



Likelihood analysis-- four body mass shapes

V+Jets shape cross-check

- ❖Generate pseudo-data samples with alternate model
- ❖ fitted with the nominal (Polynomial) model
- ❖look at means of the pull distributions
- ❖ the bias is well under control within 20% of the statistical uncertainty



Results:

four body mass fit to data, limit etc.

Fit to the m_{lvjj} spectrum & limit:

❖**Binned maximum likelihood fit to the m_{lvjj} data spectrum in the m_{jj} signal region**

❖**Shape:**

➢ All except V+Jets comes from simulation (previous step)

❖**Yields:**

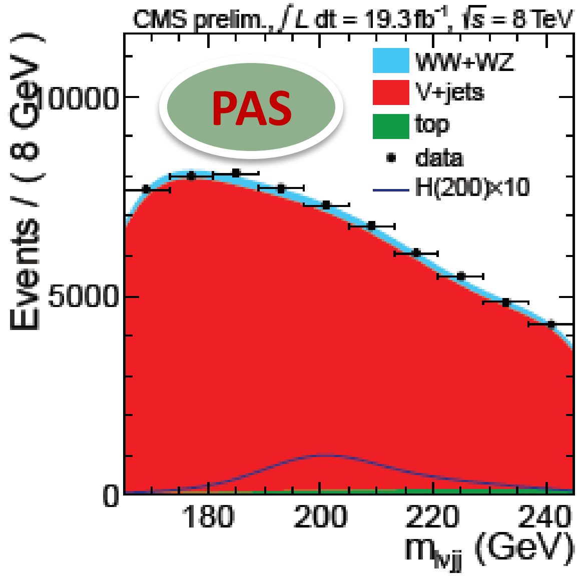
All except V+Jets comes from theory.

➢ V+jets yield comes from m_{jj} sideband fit

❖The fit under the **background only hypothesis** and the **S+B hypothesis** are performed within the combine machinery.

❖**No excess in data observed.**

μ



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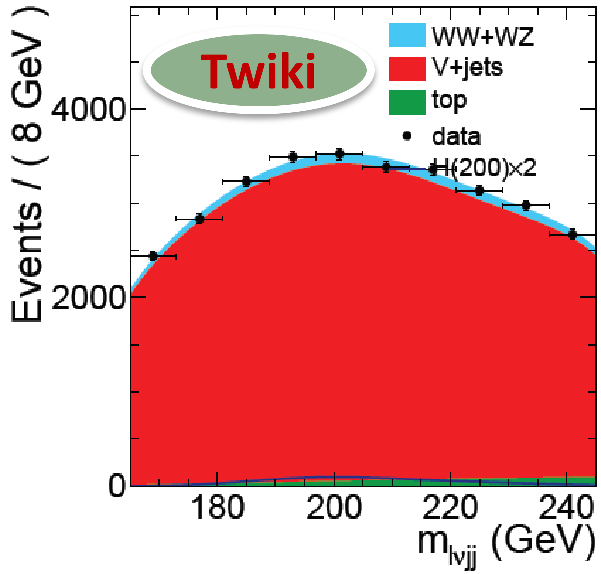
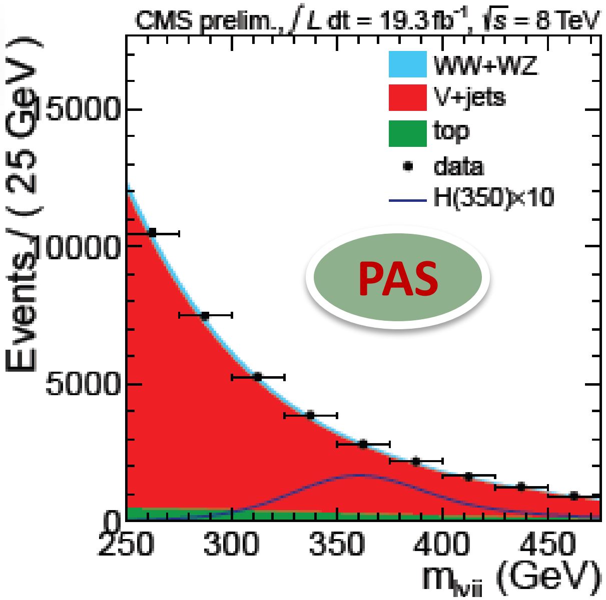
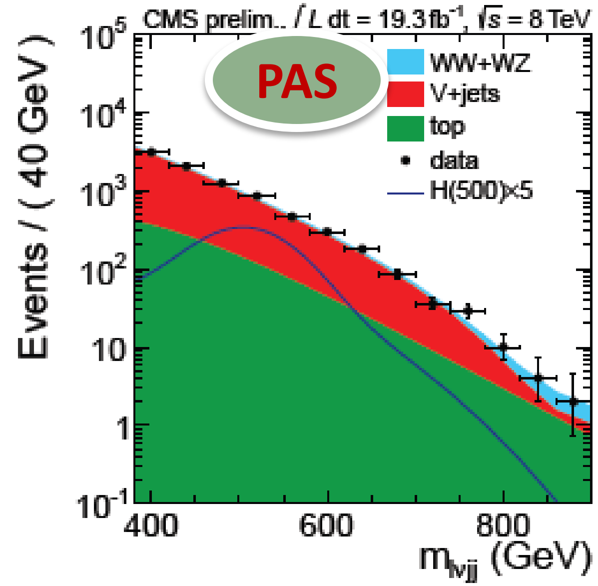


Results– Unblinded four body mass distribution

μ





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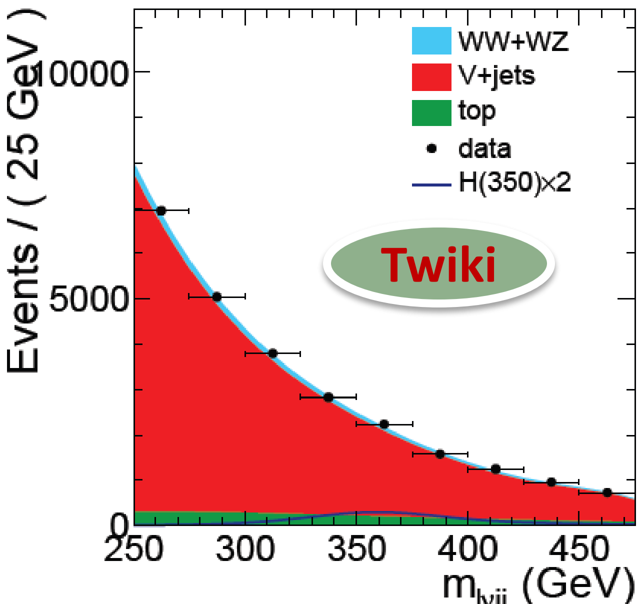
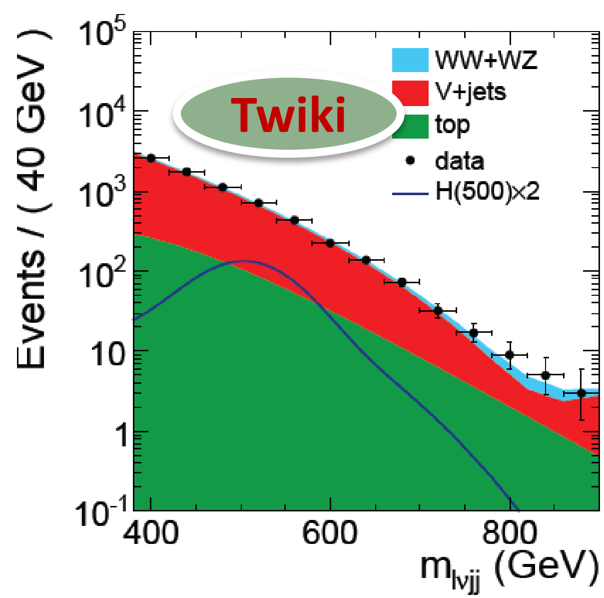


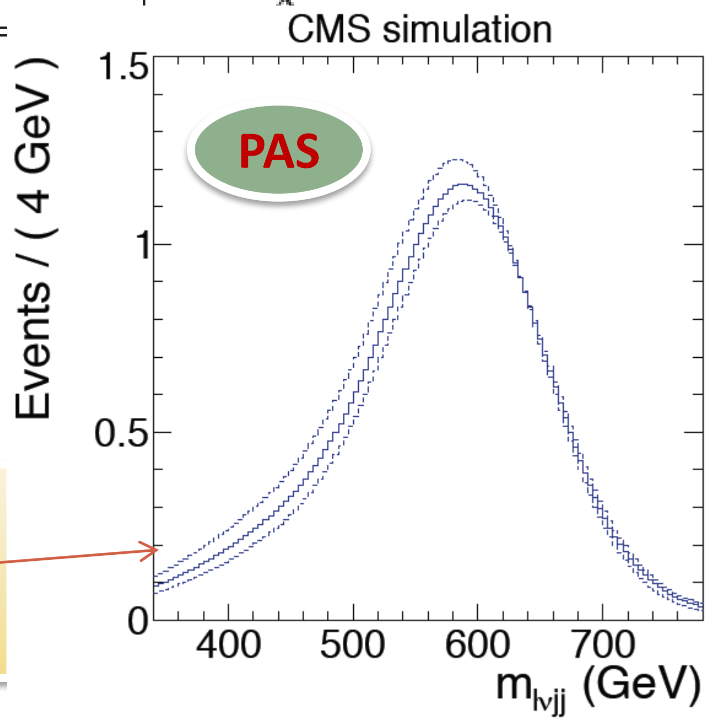


Results: Sources of systematic error

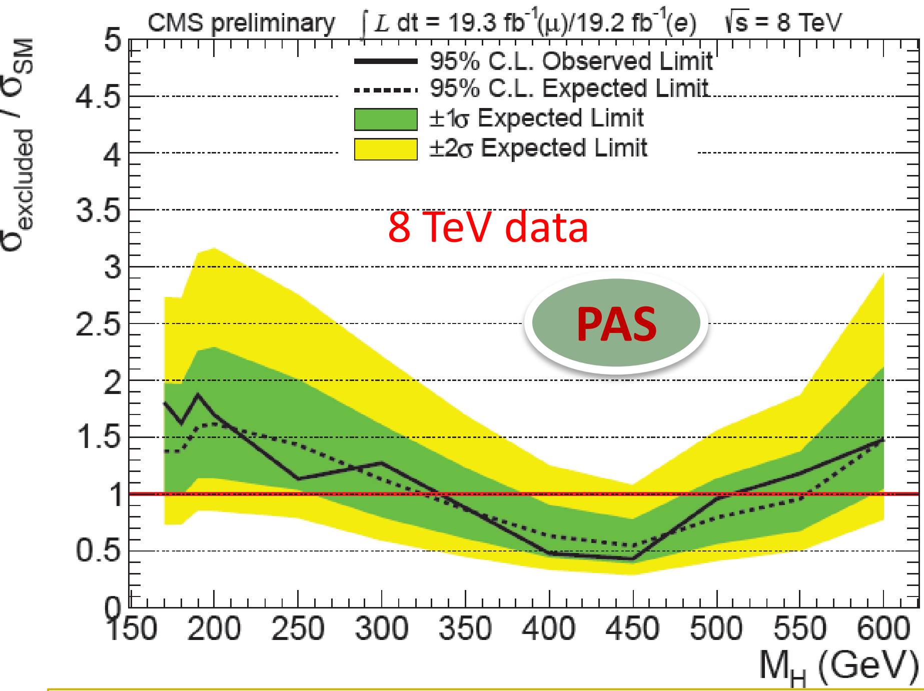
Source of uncertainty	Magnitude	V+jets	Top	Diboson	Higgs signal
V+jets $m_{\ell\nu jj}$ shape	Det. by fit	X			
V+jets normalization	0-2%	X			
Higgs boson cross section	10-11%				X
Likelihood selection	10%				X
Theory acceptances (PDF)	1-2%				X
Luminosity	2.6%		X	X	X
Lepton selection efficiency	1-2%		X	X	X
Lepton trigger efficiency	1%		X	X	X
Signal shape (interference)	See Fig. below				X

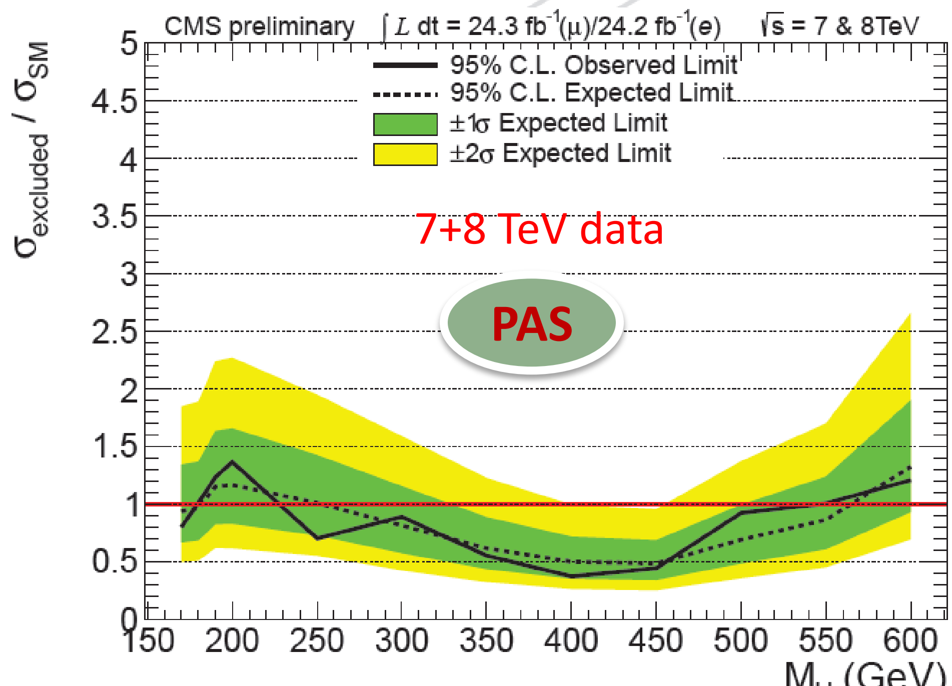
Systematic in signal shape at high mass driven by the interference between gg → WW and gg → H → WW

The shape variation from interference for the Signal m_{lvjj} distribution, for higgs mass 600GeV



Results: Probe of signal strength vs. Higgs mass





No evidence for additional Higgs-like boson is found and 95% exclusion limits on its production cross section has been obtained.

Observed: 8TeV : 335-500 GeV excluded at 95% CL.

7+8TeV : 170-180GeV and 230-545 GeV excluded at 95% CL.

Expected: 8TeV : 325-555GeV expected exclusion at 95% CL.

7+8TeV : 170-180GeV and 255-565 GeV exclusion at 95% CL.

Results: BSM interpretation

➢Search for electroweak singlet scalar where a heavy higgs boson mixes with higgs at **126GeV** .

➢Couplings related by unitarity, $\mathbf{C^2+C'^2=1}$, Where C(C′) scale factor of couplings of low(high) mass higgs w.r.t. SM

➢The heavy higgs signal strength (μ') and width Γ' are:

$$\mu' = C'^2 \ (1 - BR_{new}) \ , \quad \Gamma' = \Gamma_{SM} \times C'^2 / (1 - BR_{new})$$

$\mathbf{BR_{new}}$ is the branching ratio of heavy higgs to non-SM like decay modes.

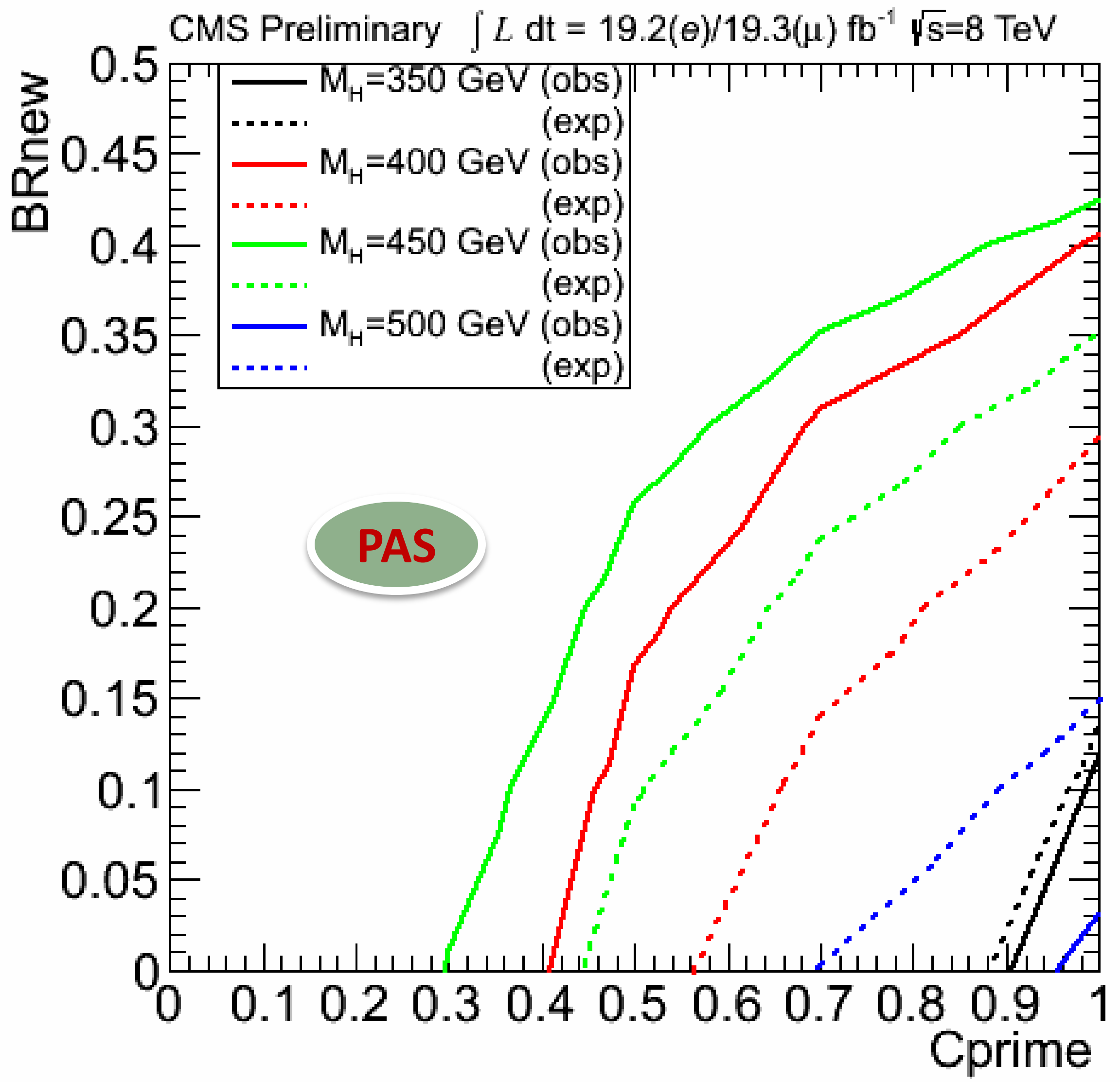
➢Interference between the BSM Higgs and the background :

$$(\mu + I)_{BSM} = \mu_{SM} \ C'^2 + I_{SM} \ C'$$

$\mu(I)$: signal strength (interference) in the BSM and SM cases.

Results: BSM limits

- **A scan of grid points in C' vs. BRnew vs. M_H space.**
- Signal strength r =1contours
- Space below contour, on right are excluded
- Results as expected: most sensitive to the scenario with a lone heavy SM Higgs (particularly in the middle of our mass search window), which corresponds to C'=1.0 and BRnew=0.0.



Results: Summary

- We have a revised analysis of the semi-leptonic WW final state with the full 8 TeV dataset.

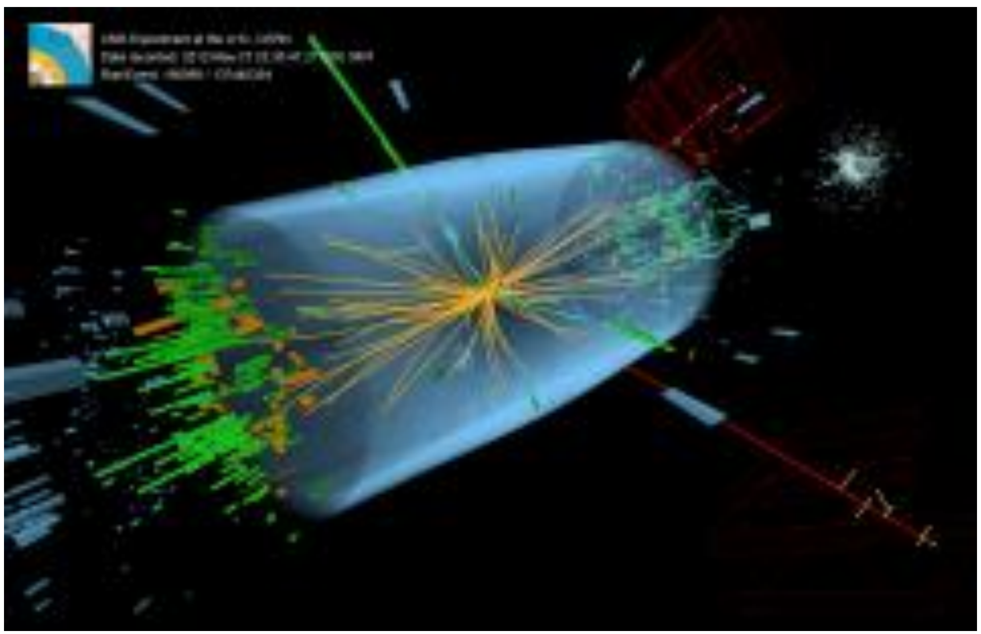
- **No evidence for additional Higgs-like boson is found and 95% exclusion limits on its production cross section has been obtained.**

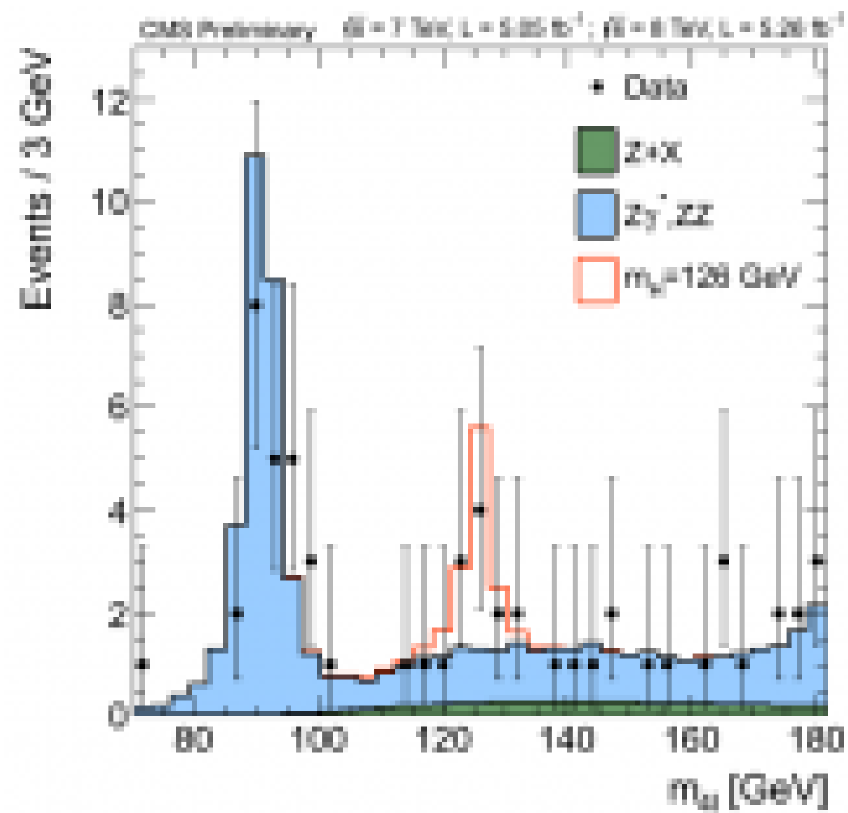
- Beyond Standard Model Interpretation performed and limits extracted.
- Documentation
  - AN-12-463
  - HIG-13-027
- **We are seeking Approval for this result for its inclusion in the forthcoming high mass paper, HIG-13-031.**

BACK UP

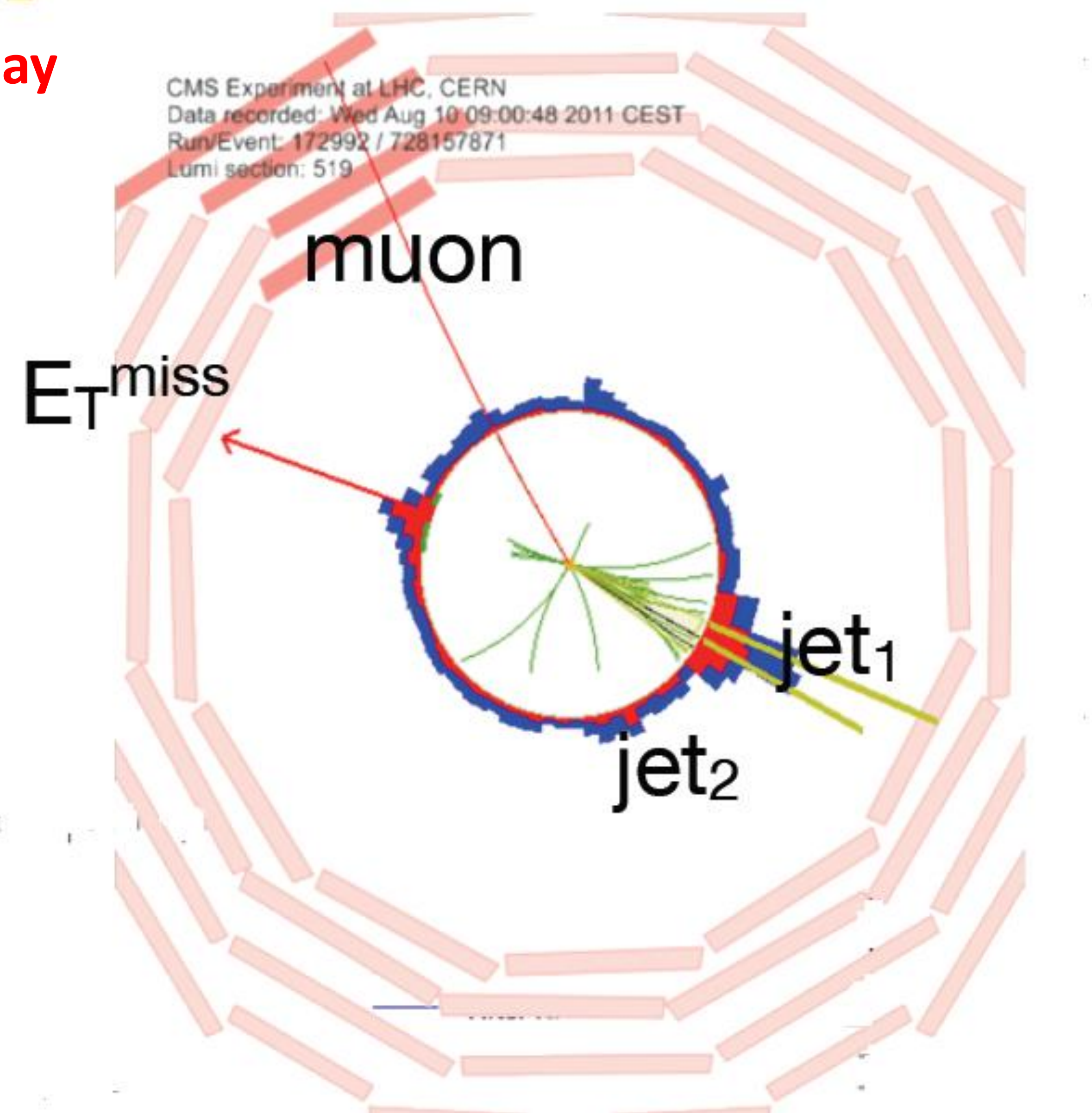
SM Higgs discovered at 125 GeV, Is that end of road ?

Ans : No

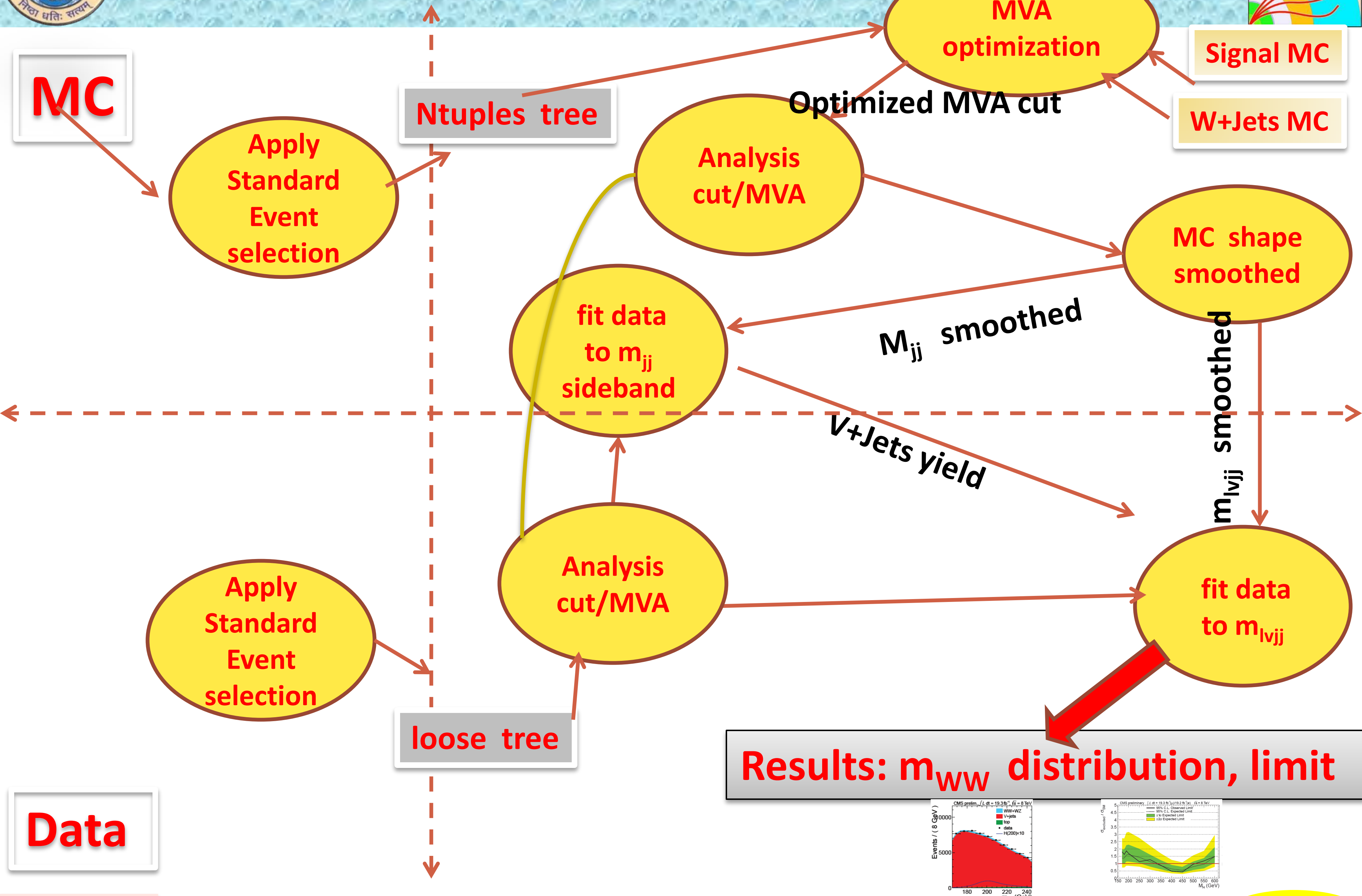




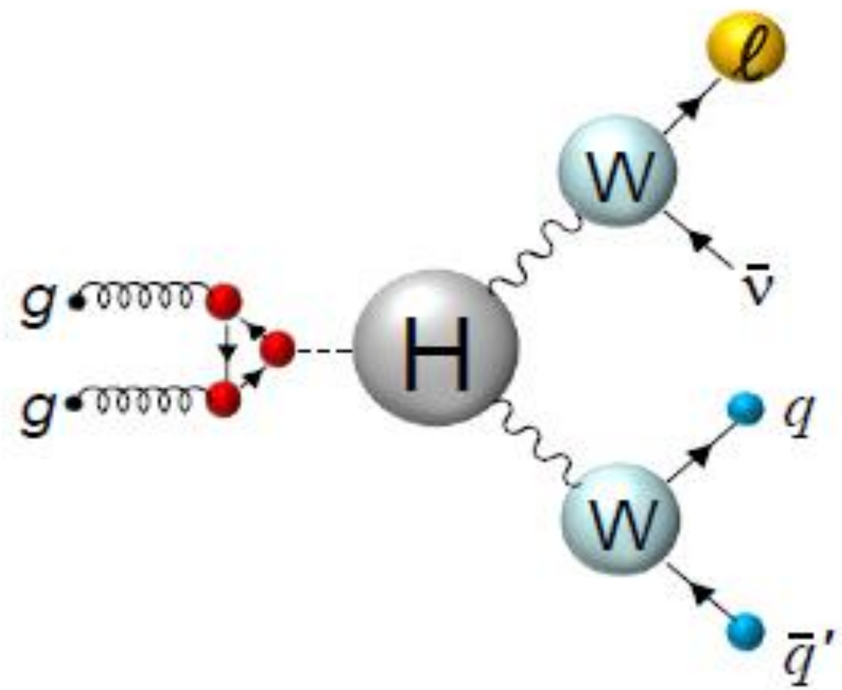
Event Display



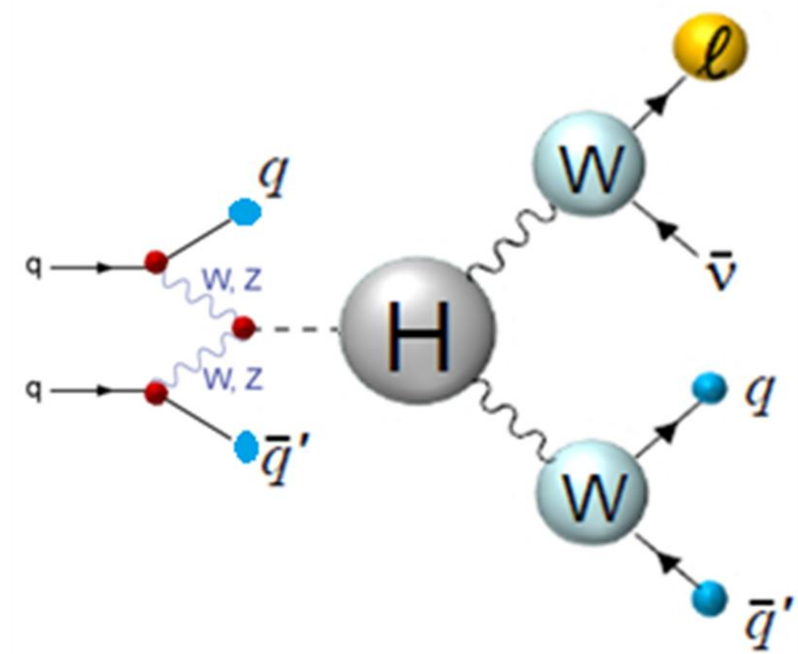
Strategy



MC
Apply Standard Event selection
Ntuples tree
MVA optimization
Signal MC
W+Jets MC
Optimized MVA cut
Analysis cut/MVA
MC shape smoothed
fit data to m_{jj} sideband
M_{jj} smoothed
V+Jets yield
m_{lvjj} smoothed
Analysis cut/MVA
fit data to m_{lvjj}
Apply Standard Event selection
loose tree
Results: m_{WW} distribution, limit
Data



g
g
H
W
W
ℓ
$\bar{\nu}$
q
$\bar{q}'$



q
q
W, Z
W, Z
q
$\bar{q}'$
H
W
W
ℓ
$\bar{\nu}$
q
$\bar{q}'$

Sample and Software

CMSSW_5_3_2_patch4 for both Data and MC Processing

Trigger: Single Lepton trigger:

Muon channel :   ('HLT_IsoMu24_*','HLT_IsoMu30_*‘)

Electron channel: ('HLT_Ele27_*','HLT_Ele32_*‘)

Background Sample	Cross-section (pb)
W+jets	36257
Z+jets	3503
WW	57.1
WZ	32.3
ZZ	8.3
t¯t+jets	225.2
t/¯t+jets (t-channel)	85.5
t/¯t+jets (s-channel)	5.65
t/¯t+jets (tW-channel)	22.4

Signal Samples Cross-Section taken from:

https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt8TeV#gluon_gluon_Fusion_Process

Physics Objects

Muons : Using the official mu-POG recommendation

- https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId
- Using “thigh” and “loose” (for veto) definitions
- PF based isolation with PU correction

Electrons : Using the official e/γ-POG recommendation

- MVA ID: https://twiki.cern.ch/twiki/bin/viewauth/CMS/MultivariateElectronIdentification
- Conversion rejection
- PF based isolation (ΔR0.3) with PU correction with Effective Area
- Tight electron: WP80 triggering MVA
- Veto : WP90 non-triggering MVA
- WP definitions: https://twiki.cern.ch/twiki/bin/view/Main/HVVElectronId2012

Jets:

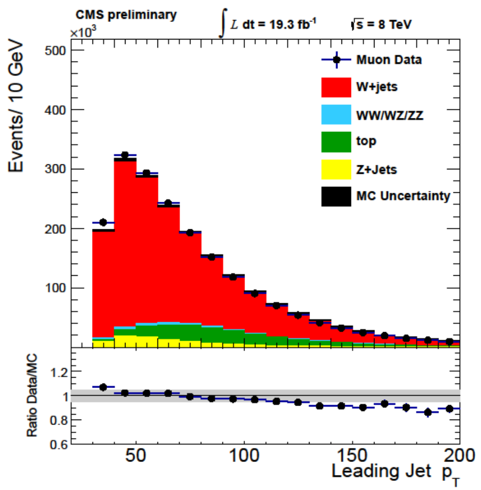
- AK5 PF jets with CHS, JEC: L1,L2,L3(residual for data)
- PU jet ID: https://twiki.cern.ch/twiki/bin/view/CMS/PileupJetID

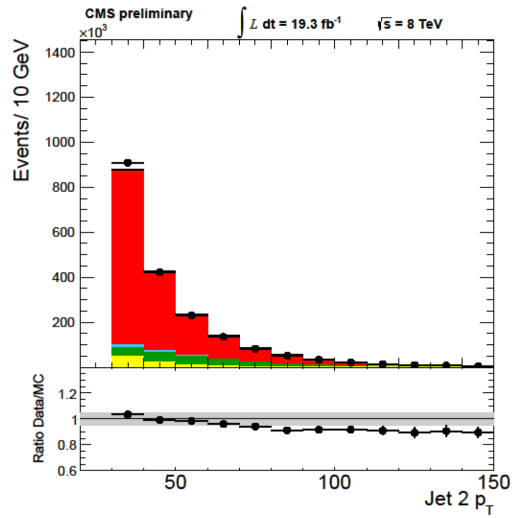
Missing Transverse Energy:

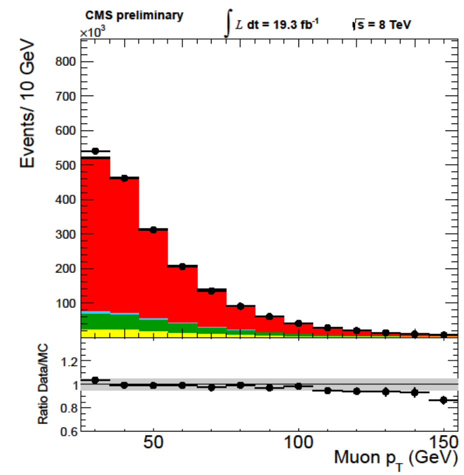
- PF MET : type-I and shift (phi modulation) corrections

Data/MC Comparisons

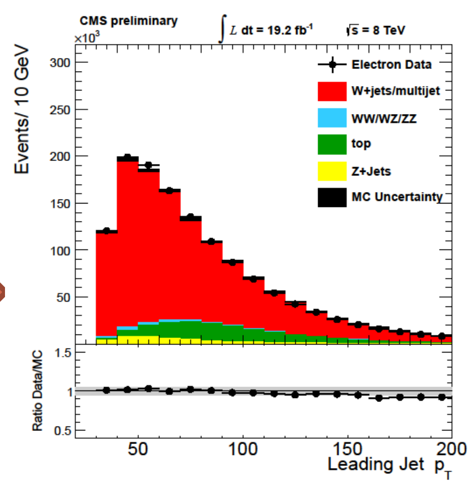
Muon

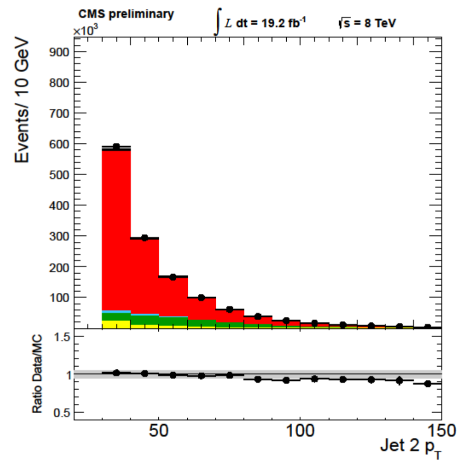


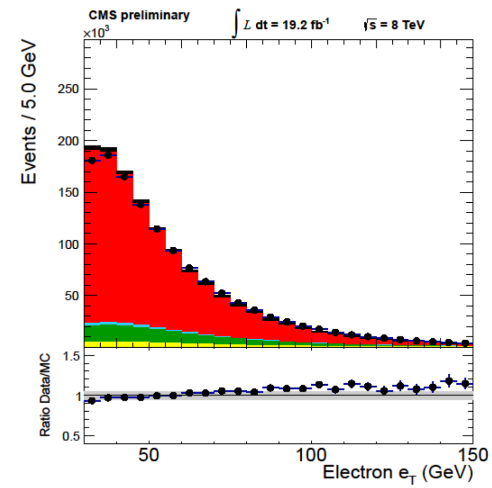




Electron

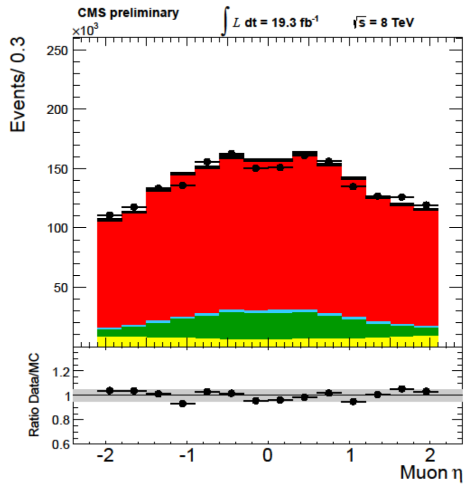


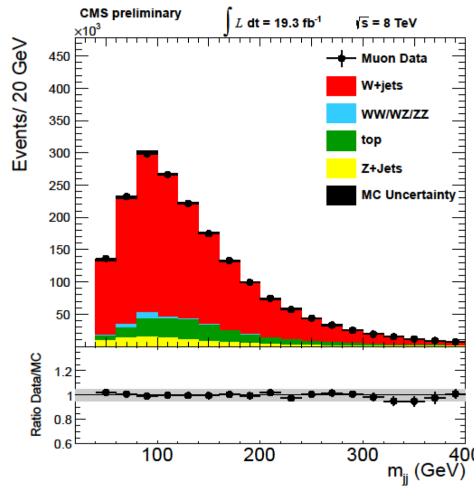


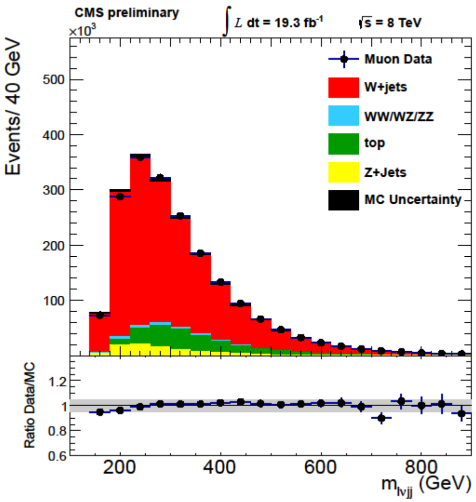


Data/MC Comparisons

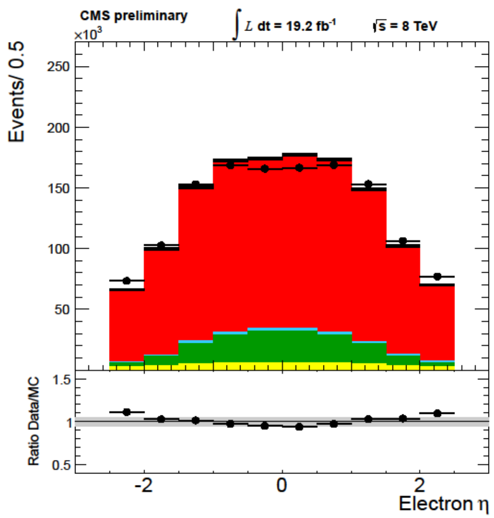
Muon

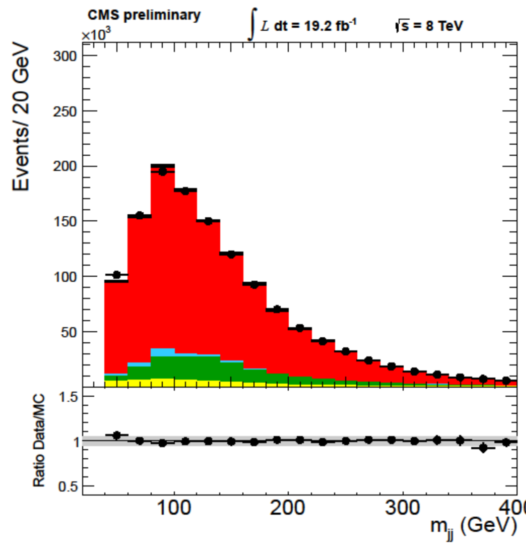


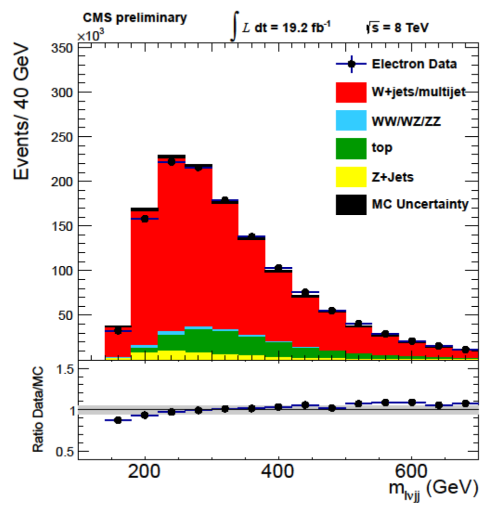




Electron

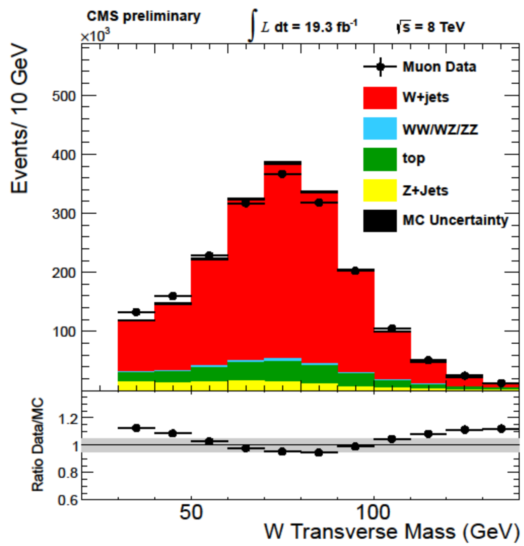


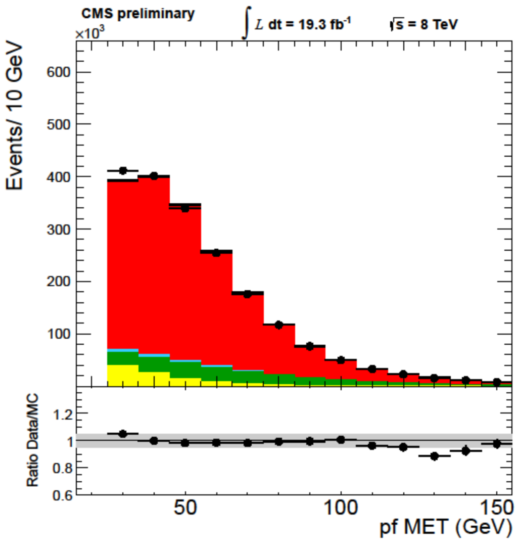




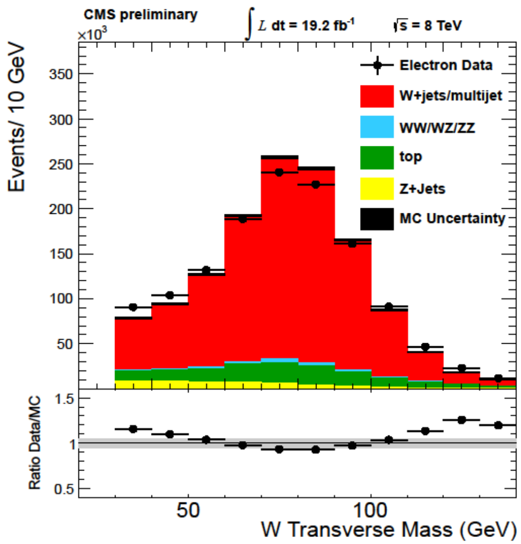
Data/MC comparisons (Leptonic W)

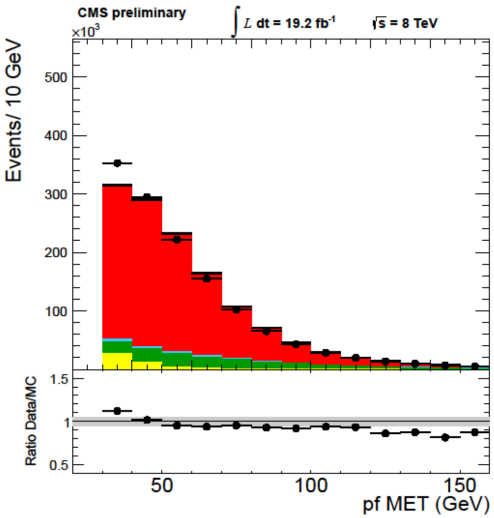
Muon→





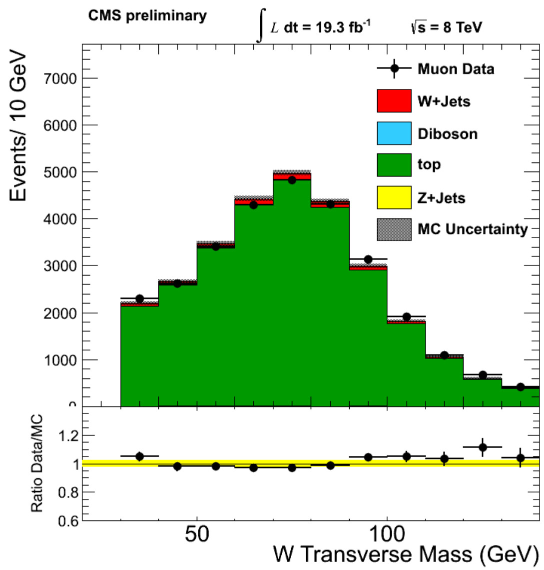
Electron→

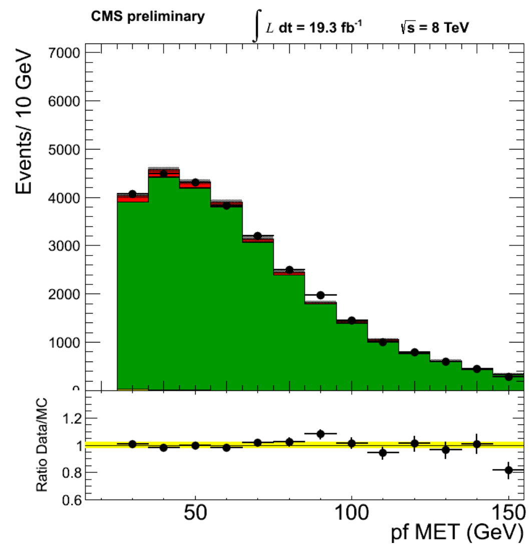




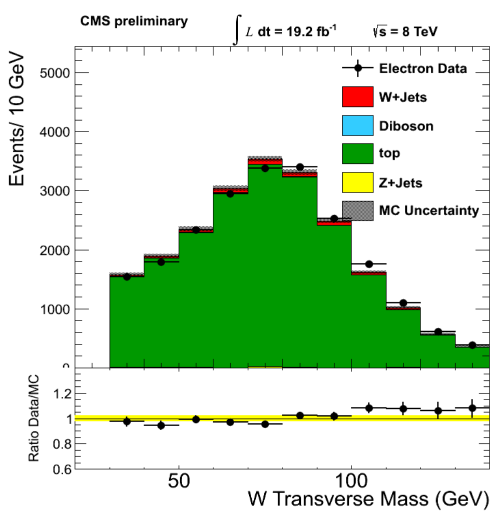
Data/MC comparisons (leptonic W)

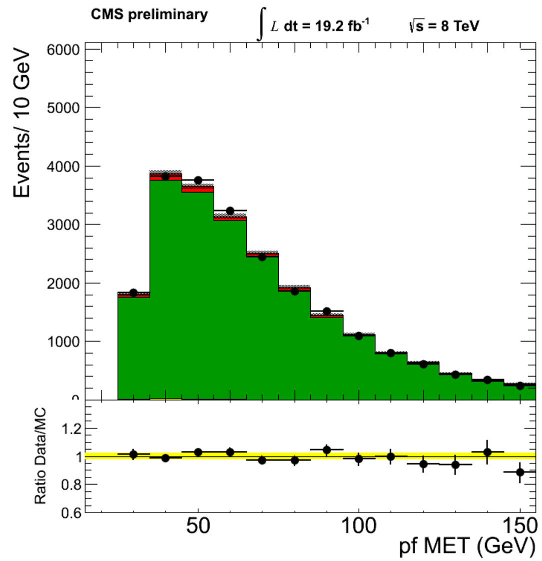
Muon→





Electron→

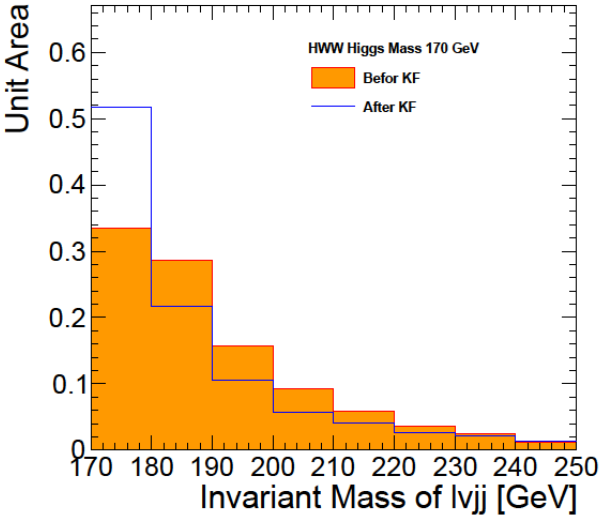


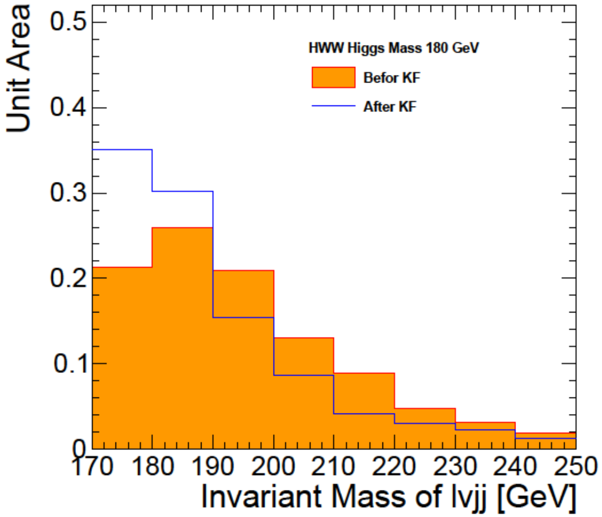


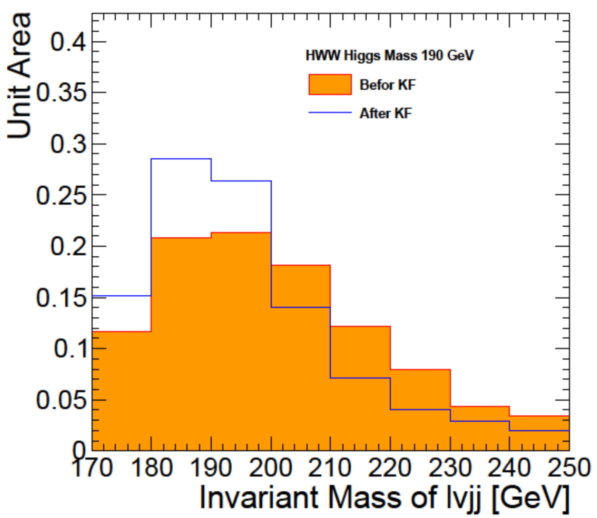
Modeling W transverse mass:

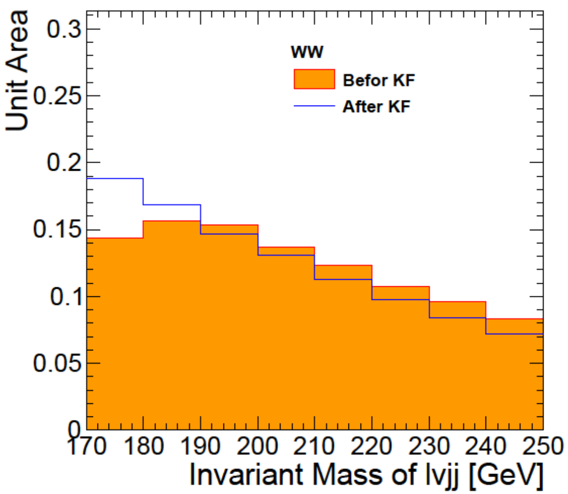
When restricting to a top enhanced region the modeling problems vanish.

Kinematic fit

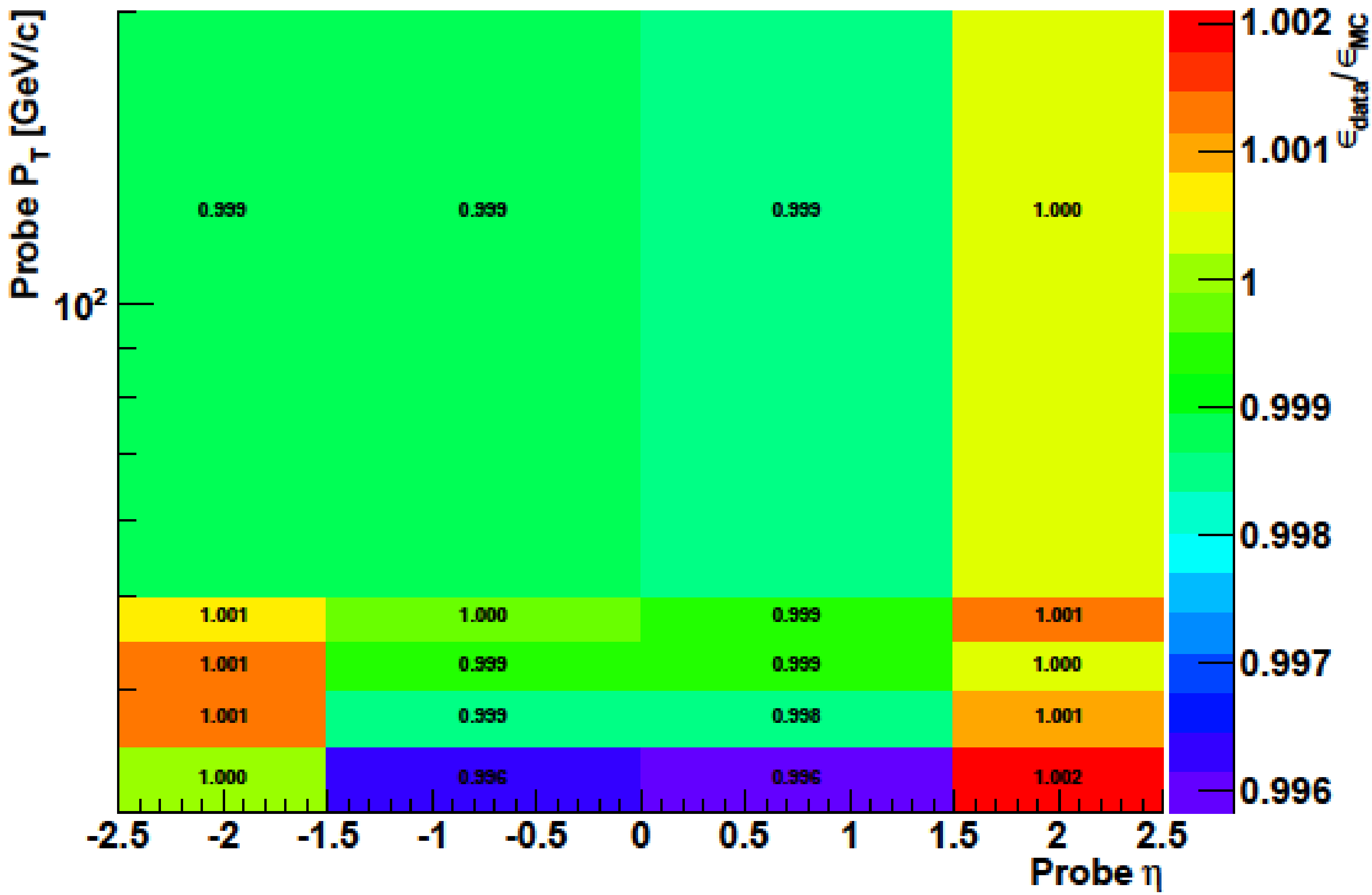




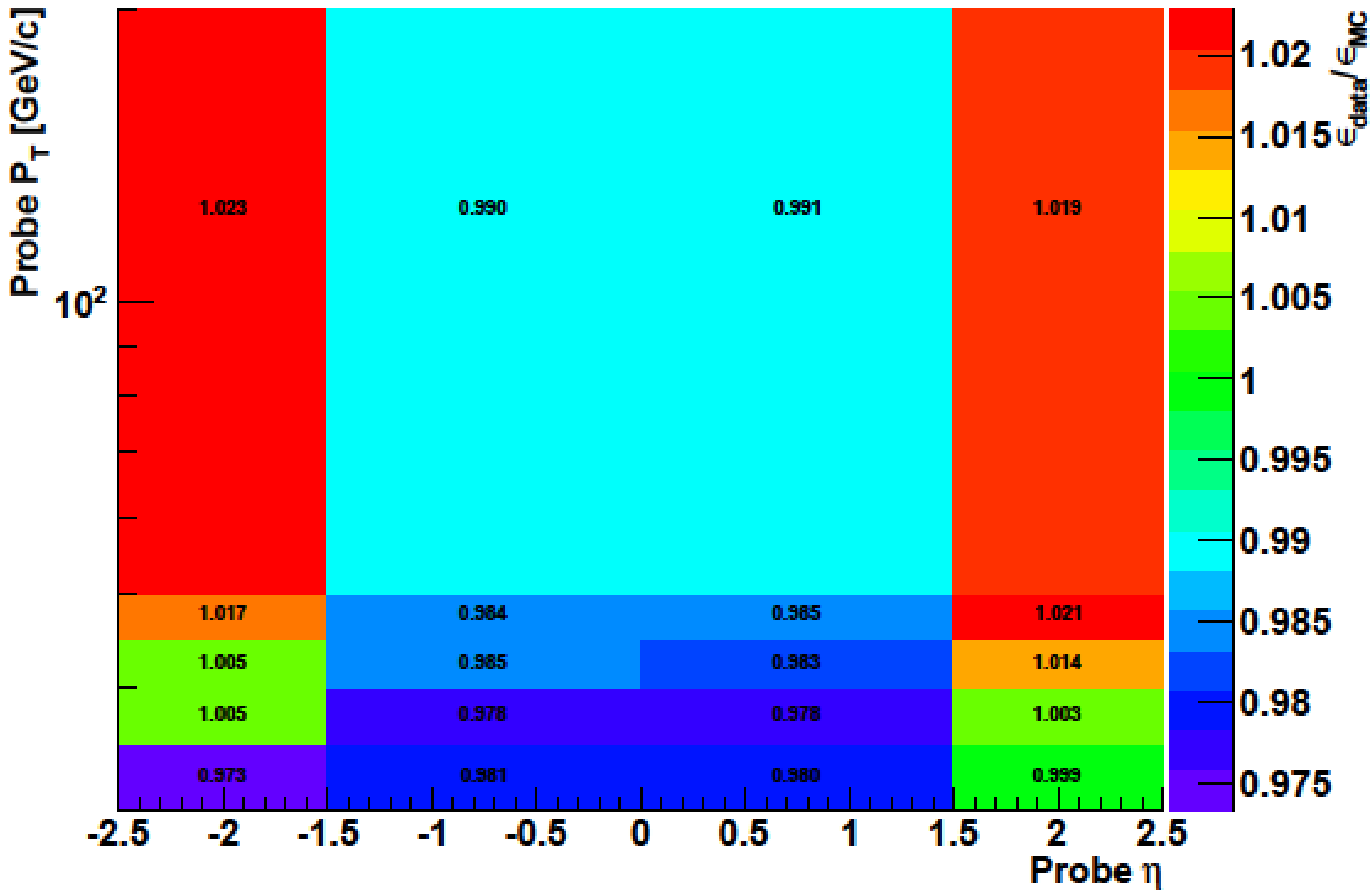




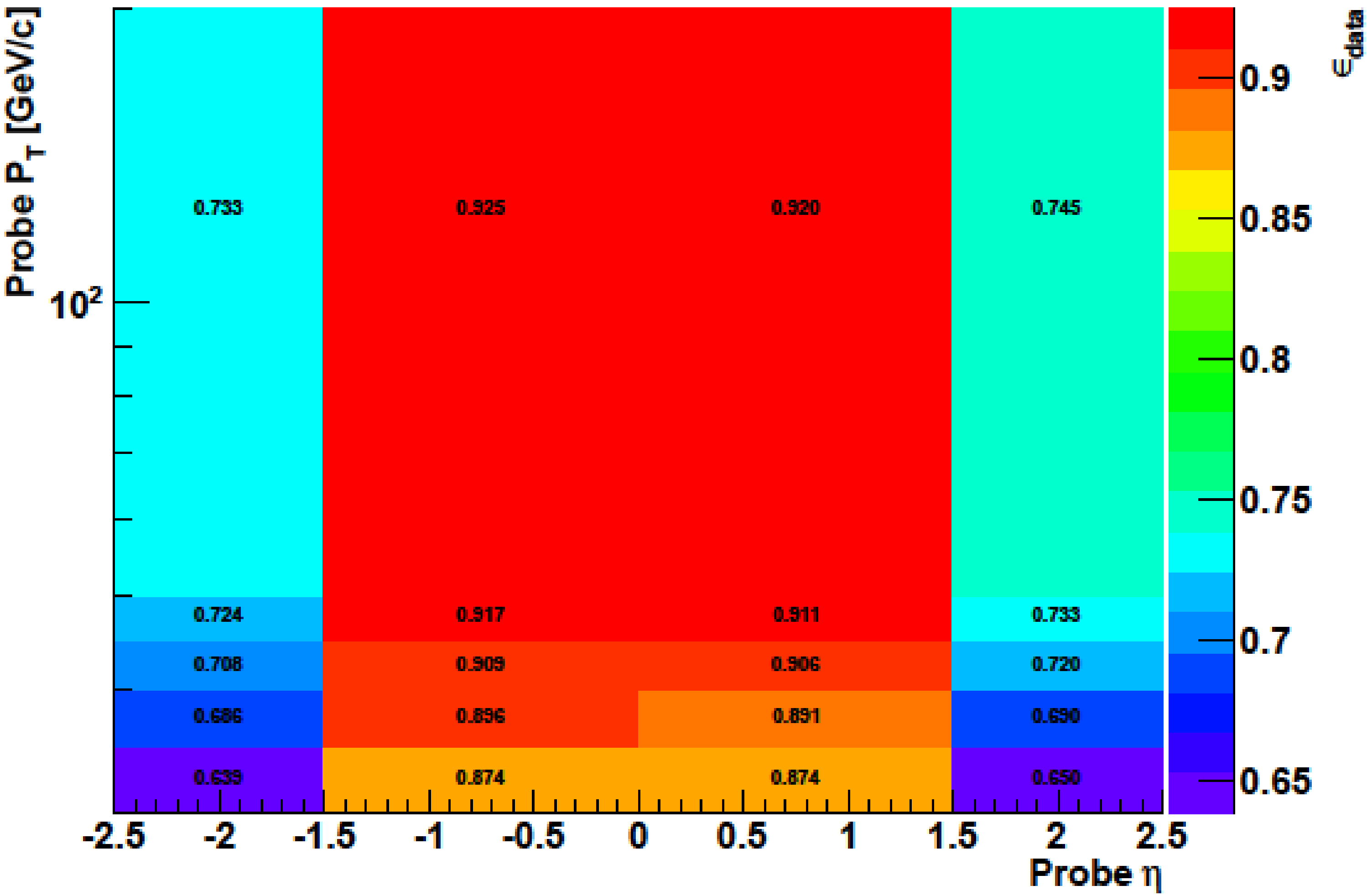
Efficiency -- Super-cluster to reconstructed electrons ε_{Reco}



Efficiency-- Reconstructed to selected electrons ε_{ID}

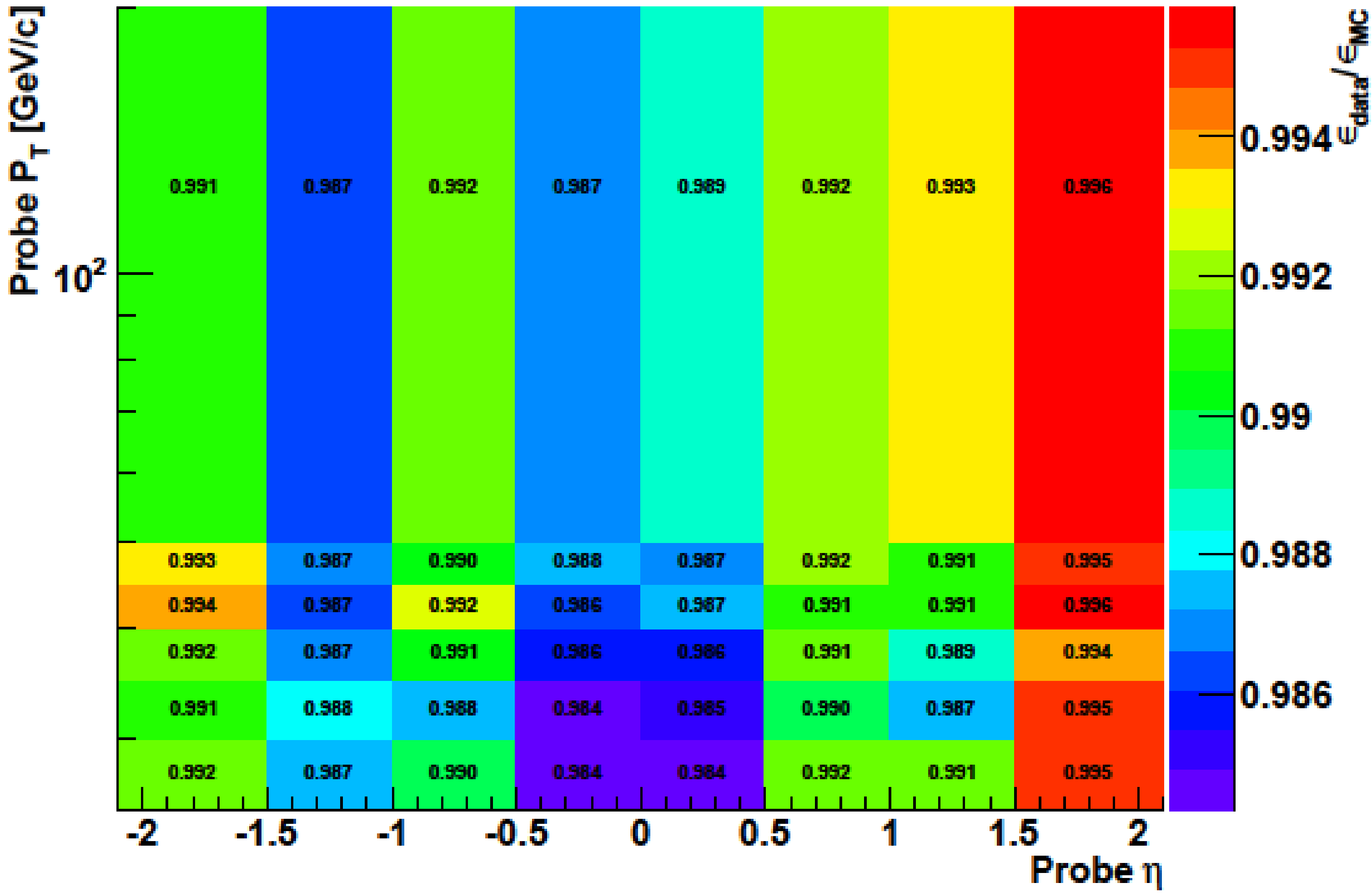


Efficiency-- selected e to HLT e(ε_{HLT})



Muon scale factor

reconstructed μ to selected μ ($\varepsilon_{ID,data}$ / $\varepsilon_{ID,MC}$)



Ajay Kumar, University of Delhi

Efficiency-- selected μ to HLT μ ($\varepsilon_{HLT,data}$)

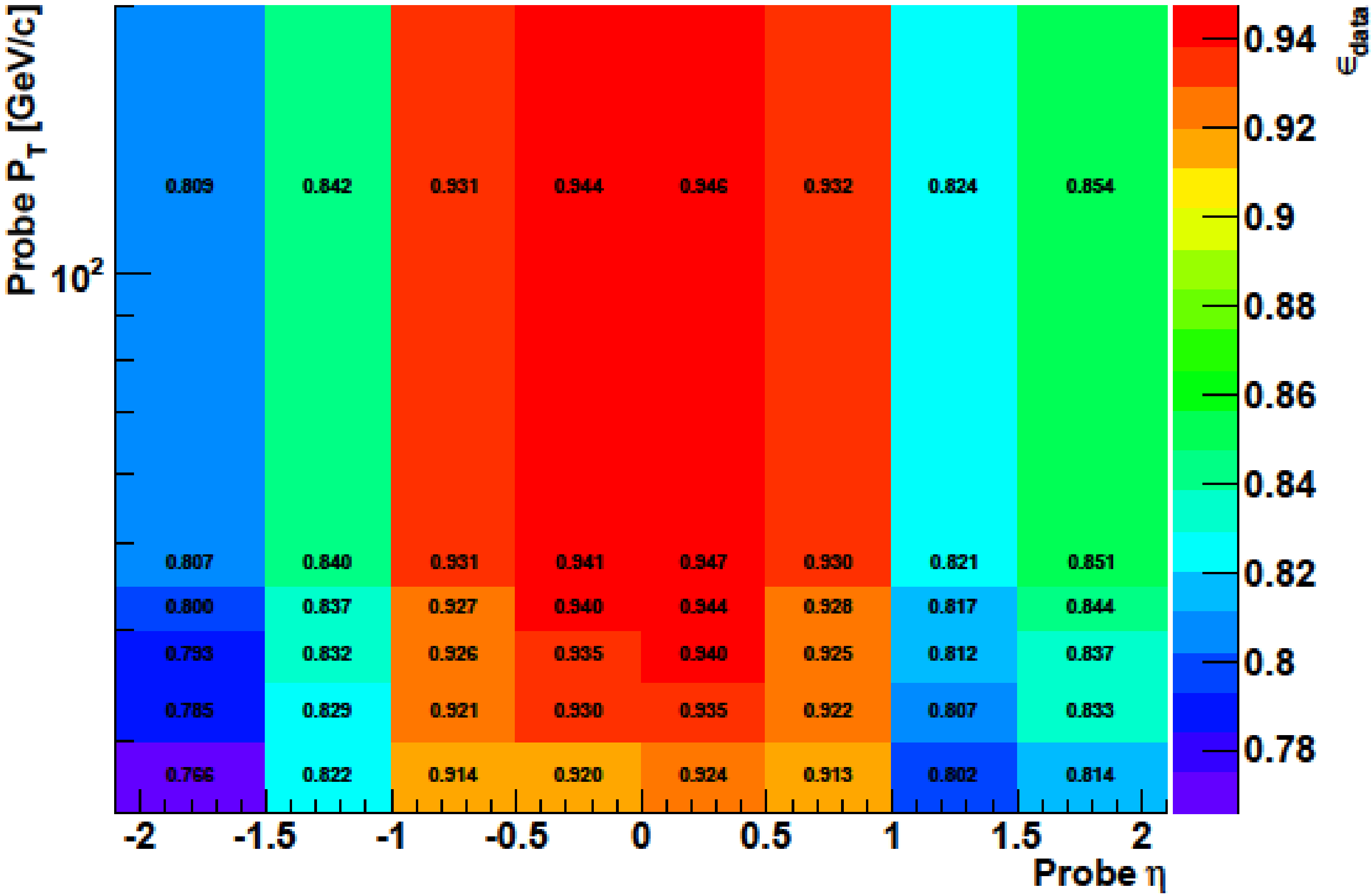


Table 8: Determination of the m_{jj} and $m_{\ell\nu jj}$ shape and normalization.

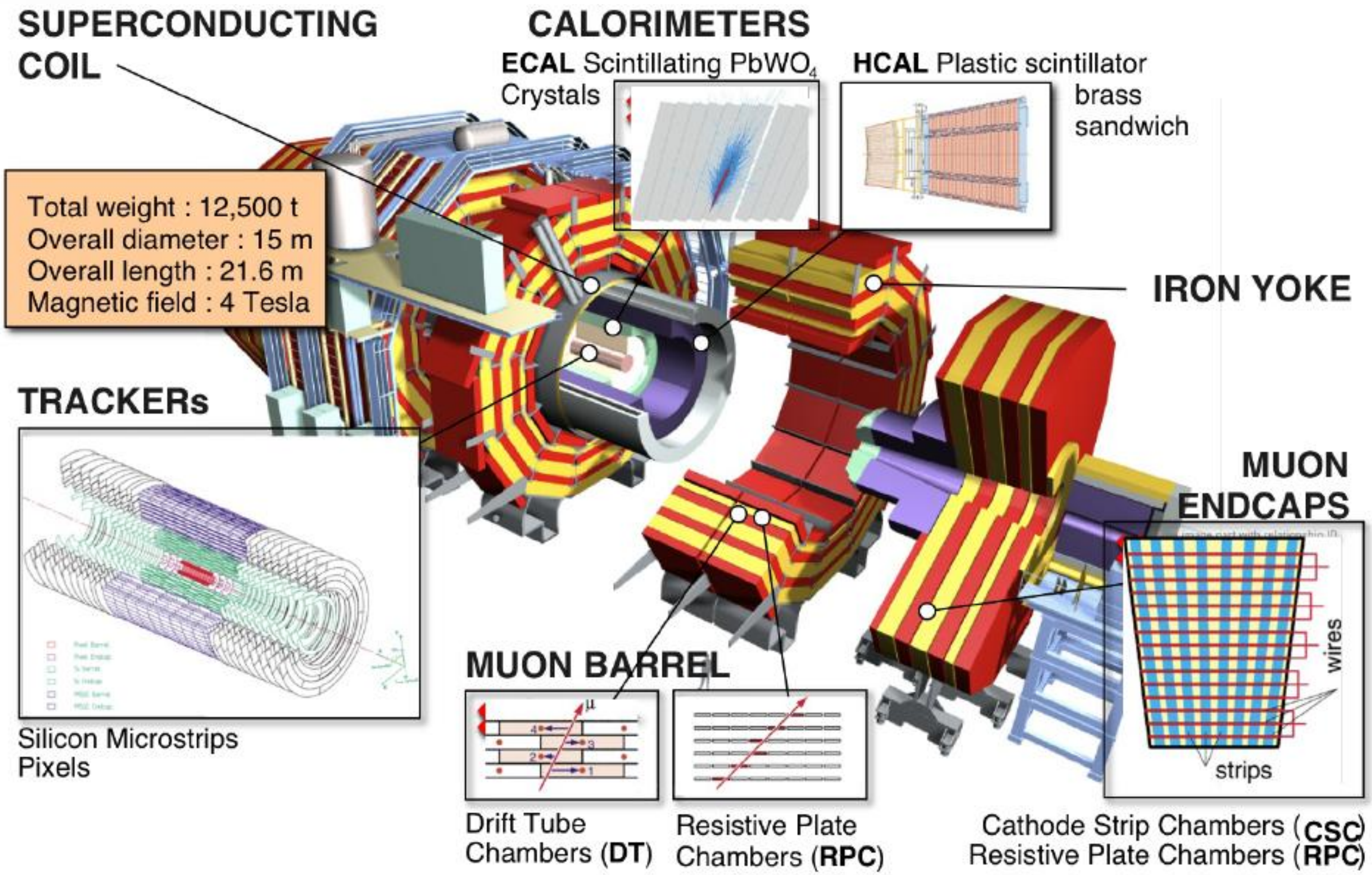
Process	Shape .	Normalization	Norm. syst.
V+jets	data/sim.	Unconstrained (m_{jj})	Unconstrained (m_{jj})
		from m_{jj} fit ($m_{\ell\nu jj}$)	m_{jj} fit uncertainty ($m_{\ell\nu jj}$)
Diboson	simulation	89.43 [68]	Lognormal: 3.4% (NLO)
top	simulation	338.74 [69]	Lognormal: 7% (NLO)

- Require on shell W_s
- Reconstruct $m_{WW} = m_{l\nu qq}$
- Define signal region m_{jj} = [65,95] GeV

- Likelihood reconstruction, 12 mass points × 2 flavours (e/μ) = 24 different likelihoods

- Two component fitting :
  - a.) W+Jets normalization from m_{jj}
  - b.) four body shape estimation
  - c.) simultaneous limit and hypothesis testing

CMS Detector and Object reconstruction

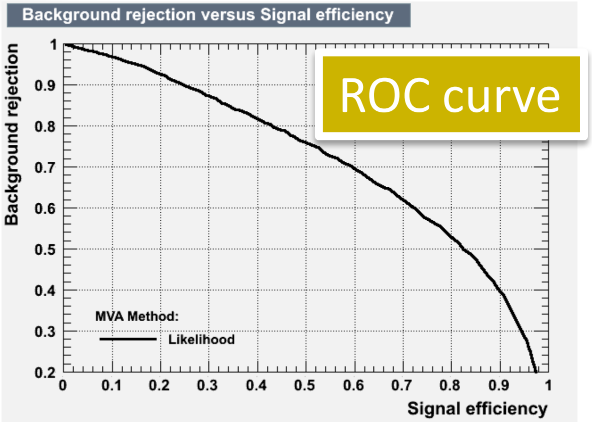


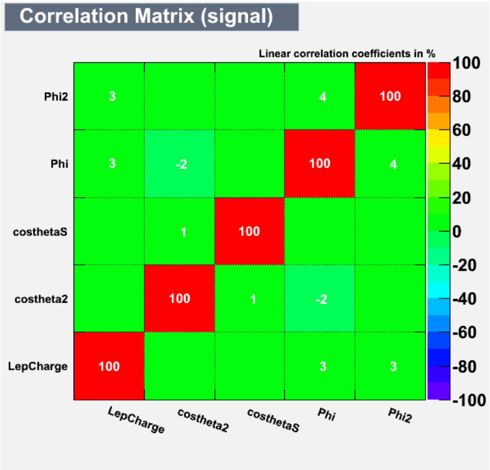
Muons are measured with the tracker and the muon system.

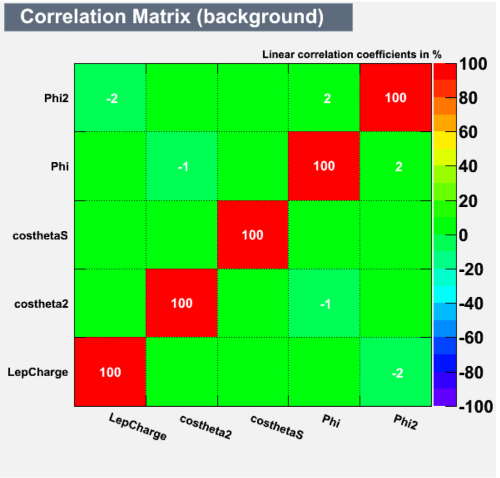
Electrons are detected as tracks in the tracker pointing to energy clusters in the ECAL

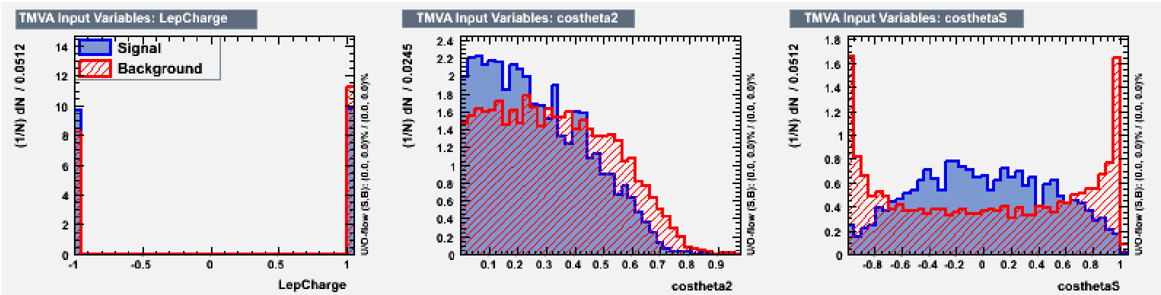
Jets are reconstructed from calorimeter and tracker information using a particle flow algorithm.

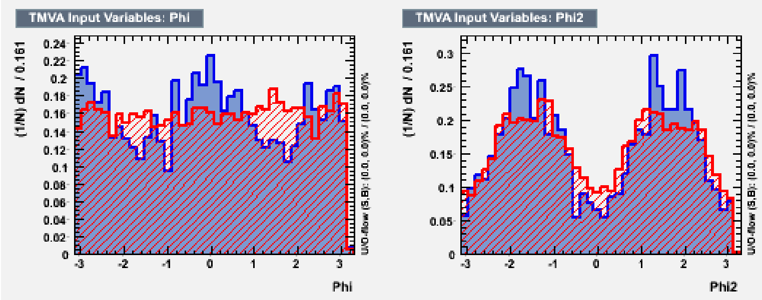
TMVA optimization





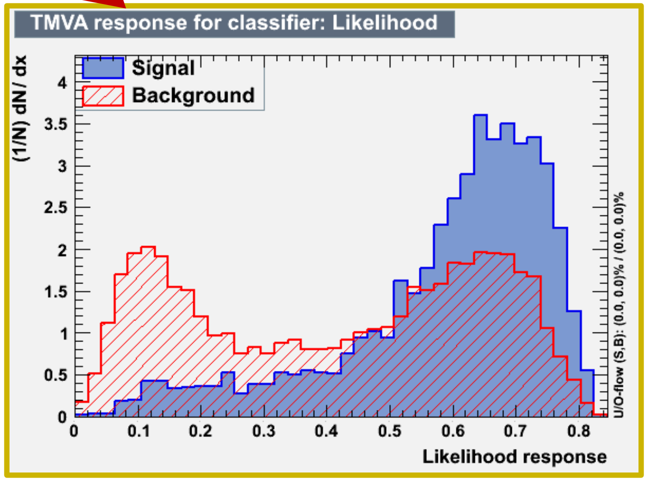






For higgs mass 250Gev, Muon Channel, Representative Plots.

Output



Likelihood analysis

Likelihood analysis

After all selections are applied:

Simultaneous fit and limit extraction using statistical combination tools used cms-wide,

1st fit: an unbinned maximum likelihood fit to m_{jj} distribution in side bands:
--Background yields

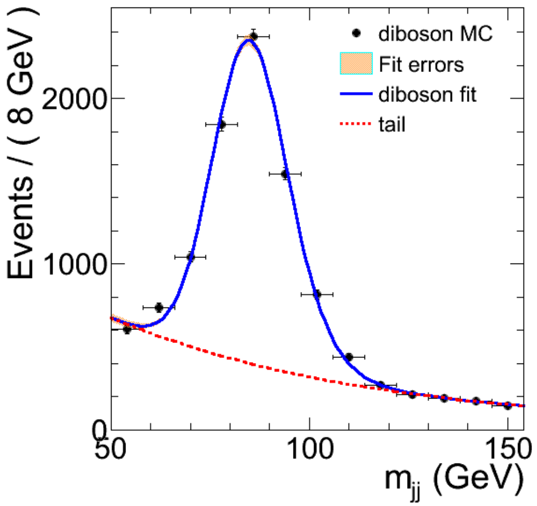
2nd fit: binned maximum likelihood fit to four body mass with simultaneous exclusion limit extraction
--four body shape, limits

The m_{jj} background models

Start with fully corrected MC:

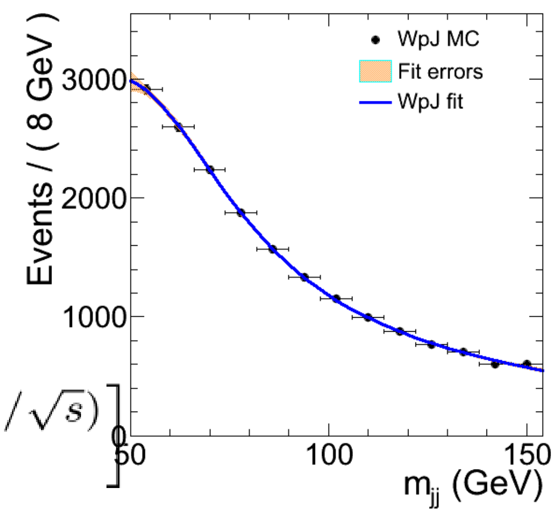
a.) Diboson: Sum of two Gaussian, means differ by the W/Z mass, widths also scaled proportional to the masses

+ a wide tail to catch poorly reconstructed events.



b.) Top: is the sum of a peaking component and a wide tail.

c.) W/Z + jets: Kinematic turn on and power law



$$\mathcal{F}_{\mathrm{V+jets}} = \frac{1}{2}\left[1+\mathrm{erf}(m_{jj}; m_0, \sigma)\right] \times \left[(m_{jj})^{-\alpha-\beta\ln(m_{jj}/\sqrt{s})}\right]$$

Values of parameters determined from MC and fixed in the fit.

Likelihood analysis--1. Background yields

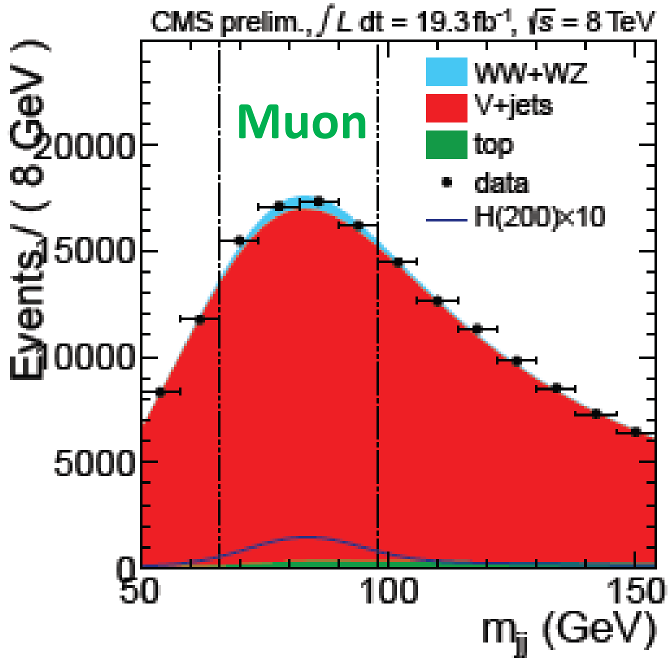
The m_{jj} fit in sidebands

❖Unbinned maximum likelihood fit to the data.

❖ Diboson and top components shapes fixed to the expectations from MC.

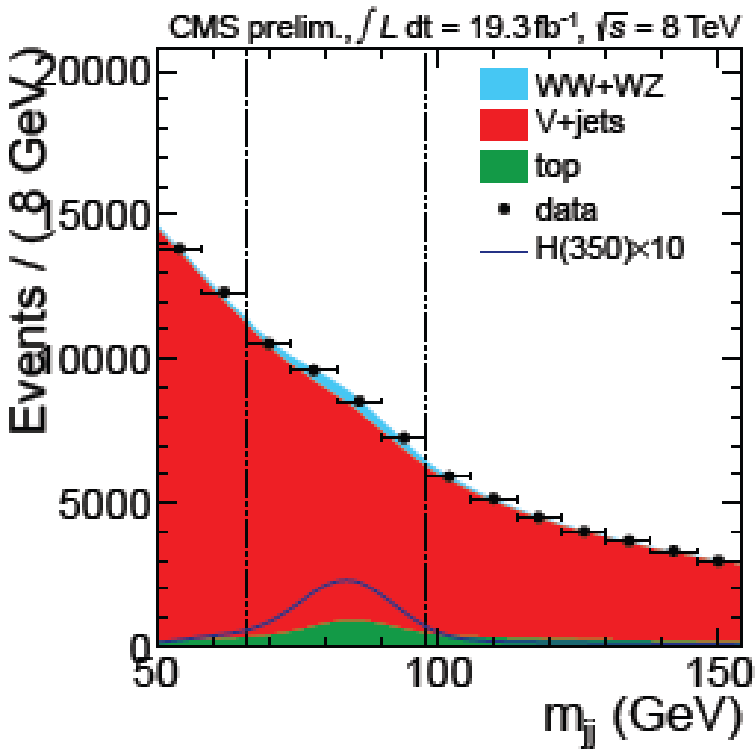
❖ W+jets shape parameters loosely constrained.

❖W+jets component yield, free parameter, others tightly constrained

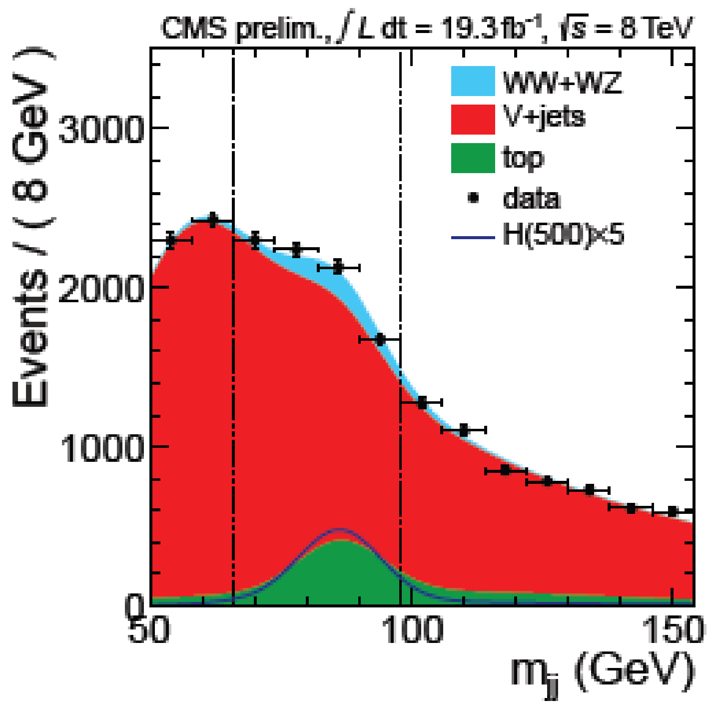


The m_{jj} fit in sidebands

Muon



Muon



❖ The W+jets yield and its uncertainty are promoted to the next step in the analysis.

The $m_{\ell \nu jj}$ models

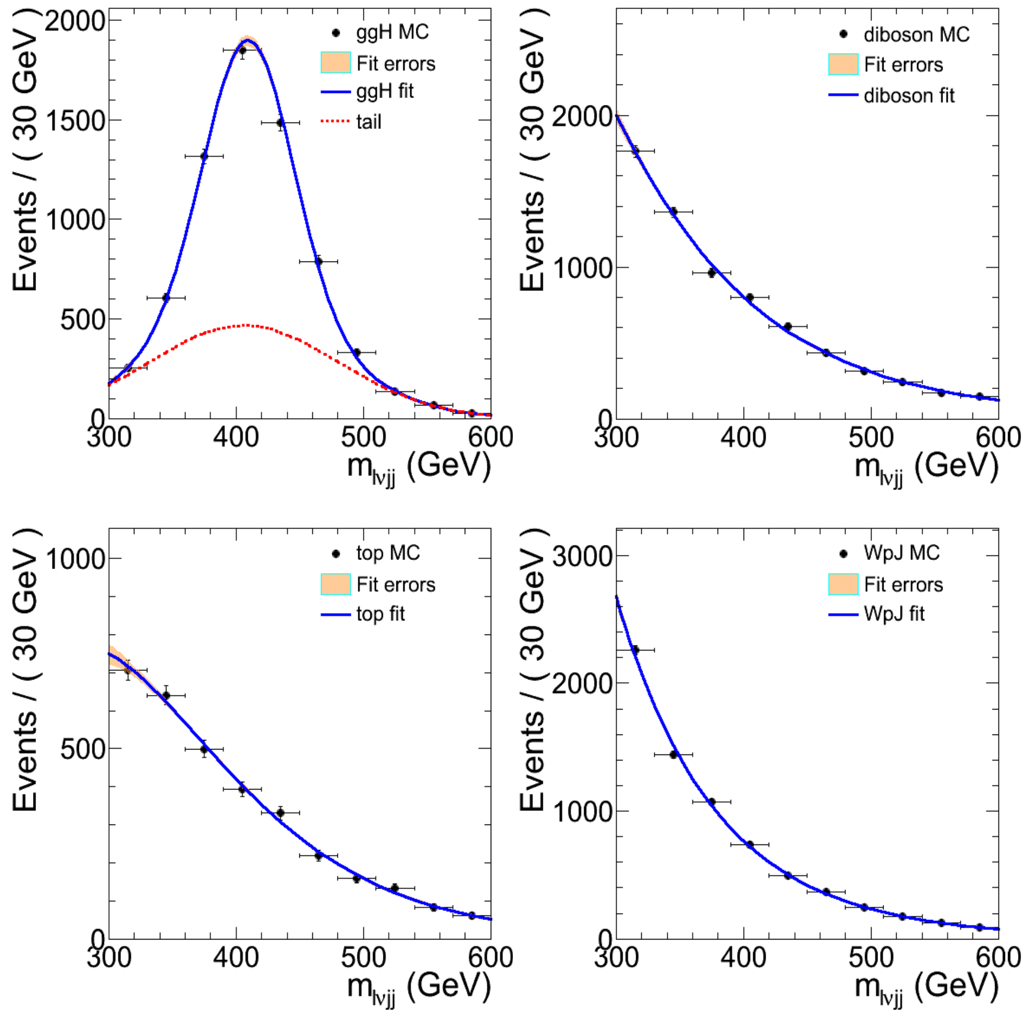
For $m_{\ell \nu jj}$ spectrum:

❖ line shapes for diboson, W/Z+jets, top, ggH and qqH production.

❖ Backgrounds except V+jets, shapes based on simulation.

❖ All backgrounds have generally monotonically falling spectra.

exceptions low mass regions, due to threshold effect on requiring 2 on-shell W' s.



The V+jets background

- dominant, least-well understood

The functional form (FF) validation:

Fit FF,

1. MC $m_{\ell\nu jj}$ spectrum in the m_{jj} signal region.
2. MC $m_{\ell\nu jj}$ spectrum in the m_{jj} sideband region.
3. data $m_{\ell\nu jj}$ spectrum in the m_{jj} sideband region.

If $P(\chi^2) < 0.001$, reject FF in favor of one with more DOF.

In all cases the shape must be able to well model the W+jets contribution to the spectrum.

4. Finally fit MC spectrum with polynomial with sufficient degrees of freedom to saturate the χ^2.

The difference between the polynomial fit and the nominal one are required to be insignificant compared to the statistical error on the nominal one.

W+jets background models

Higgs mass	Nominal $m_{\ell\nu jj}$ shape	poly. order
170	erf*power	6
180	erf*exp	6
190	erf*exp	6
200	erf*power	6
250	erf*power	6
300	erf*power	6
350	exp(quadratic)	6
400	exp(quadratic)	5
450	power	6
500	power	6
550	power	6
600	power	6

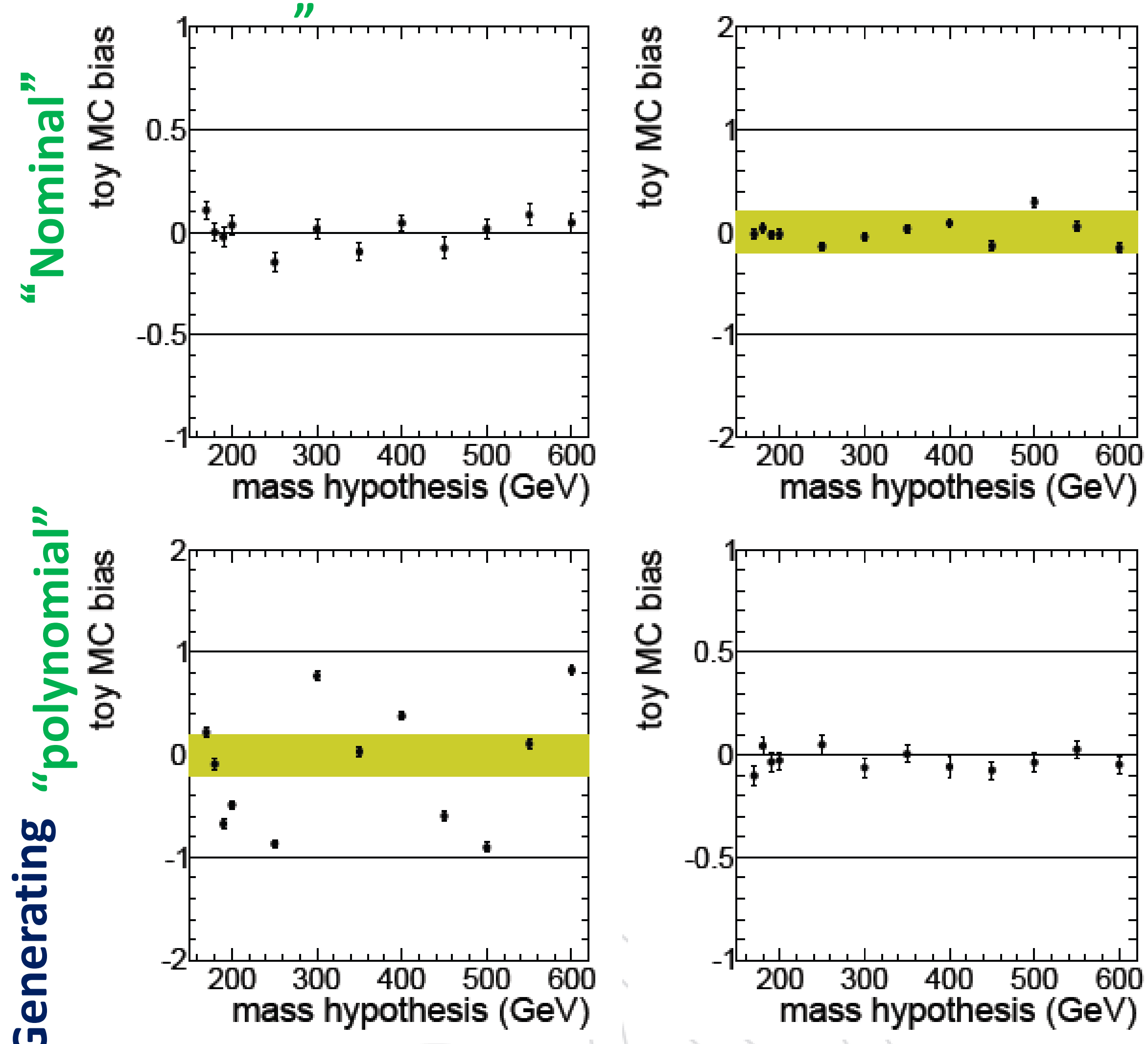
Default
Why ?
in next
2 slides.

Shape cross-check

- ❖Generate pseudo-data samples

  Nominal/ Polynomial
- ❖ fit them with either
- ❖We look : means of the pull distributions.
- ❖ we see nominal shapes not sufficiently flexible to accommodate reasonable variations in the shape,
- ❖So, polynomial as default

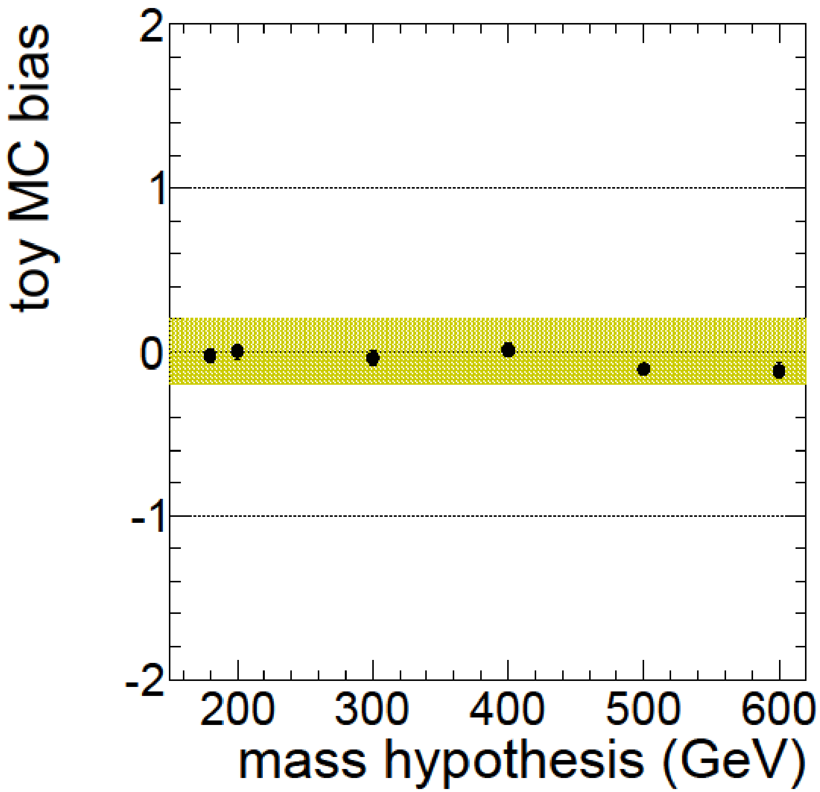
Fit model→ "nominal" "polynomial"



Alternative shape

- we replaced the exponentials in the nominal shapes with power laws and vise versa.

- When generating with this model and fitting with the polynomial model the bias is well under control.

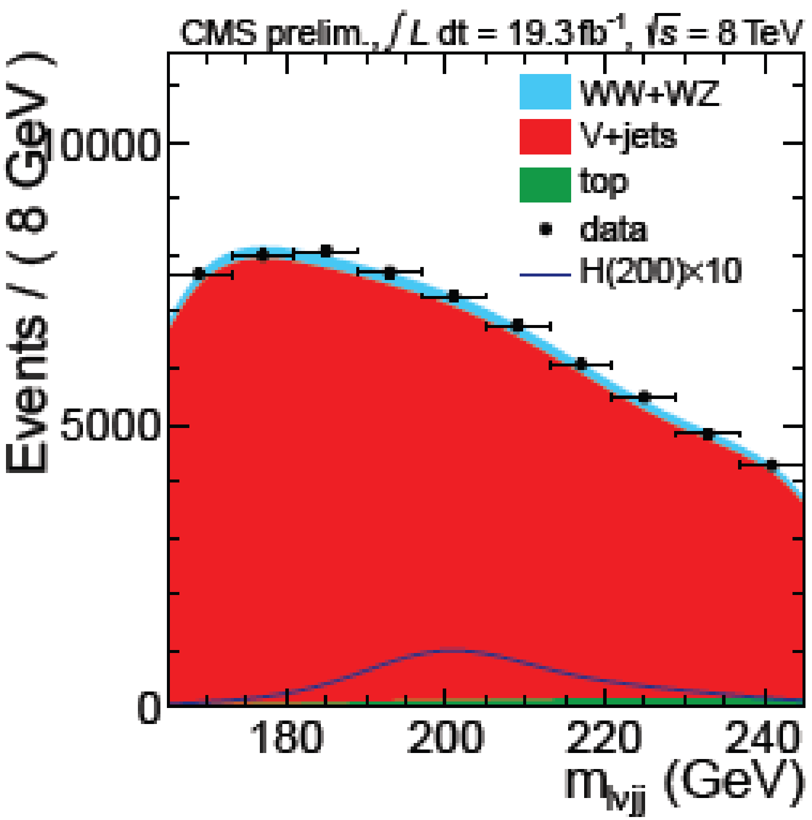


Fit to the $m_{\ell\nu jj}$ spectrum & limit:

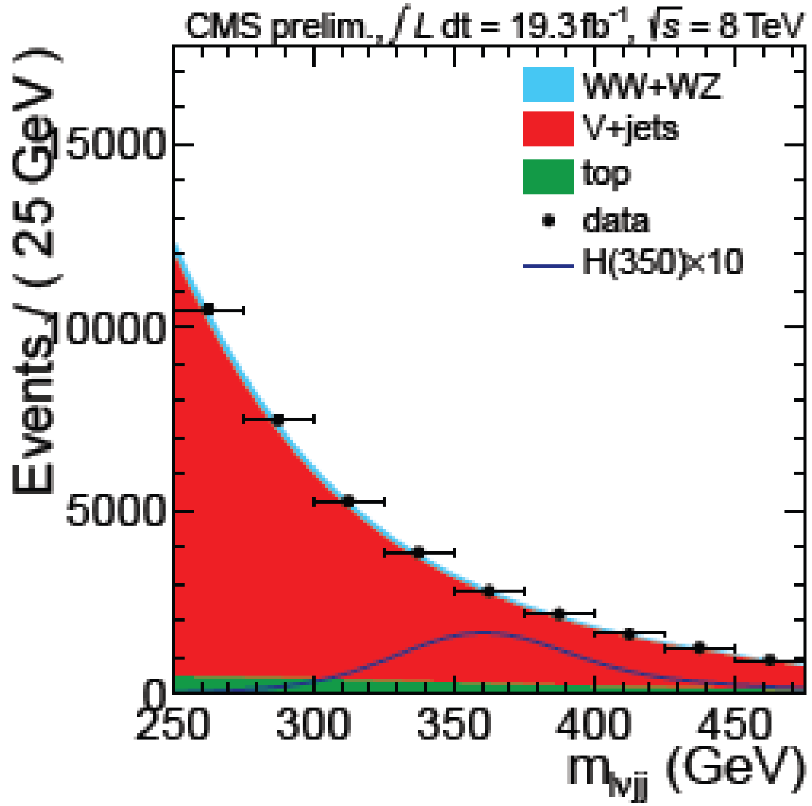
Binned maximum likelihood fit to the $m_{\nu jj}$ data spectrum in the m_{jj} signal region.

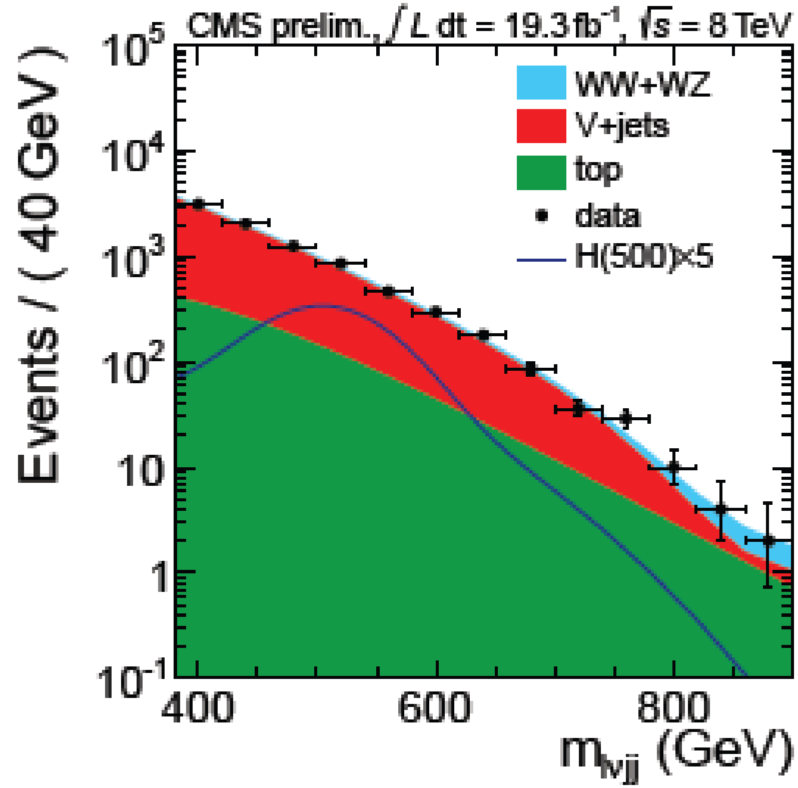
❖nuisance parameters:

- yields of V+jets from the previous step
- others yields from theory (MC)
- the shape of the V+jets background component
- other sources of systematic error enumerated subsequently.



Fit to the $m_{\ell\nu jj}$ spectrum & limit:





From this fit:

Pdf of $m_{l\nu jj}$ for each component goes as input to limit setting tool

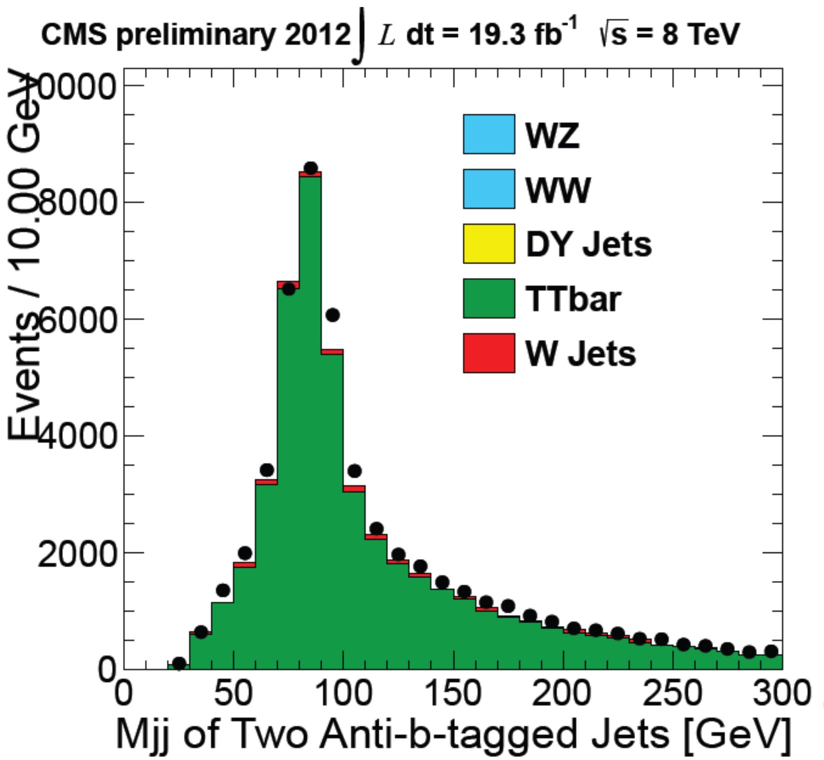
Higgs production cross-section uncertainty

ggF		VBF	
m_H	unc.	m_H	unc.
170	2.0%	170	2.0%
180	2.0%	180	2.0%
190	2.0%	190	2.0%
200	2.0%	200	2.0%
250	1.5%	250	1.1%
300	2.0%	300	0.9%
350	2.2%	350	0.8%
400	2.4%	400	0.6%
450	2.7%	450	0.7%
500	2.9%	500	0.9%
550	3.2%	550	0.9%
600	3.6%	600	0.7%

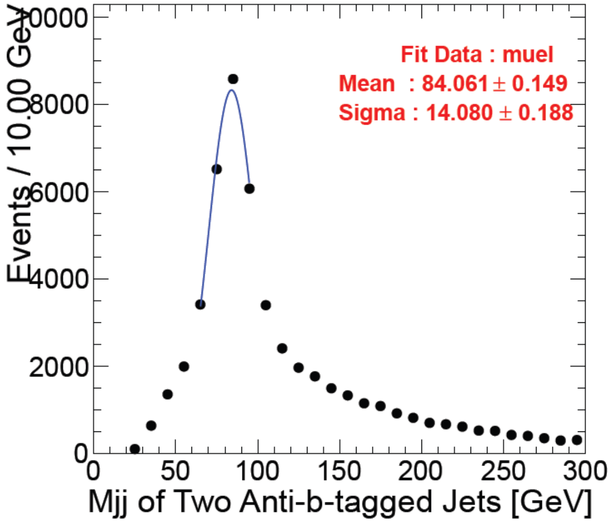
Source of uncertainty

Source of uncertainty	Magnitude	V+jets	Top	Diboson	Higgs signal
V+jets $m_{\ell\nu jj}$ shape	Det. by fit	X			
V+jets normalization	0-2%	X			
Higgs boson cross section	10-11%				X
Likelihood selection	10%				X
Theory acceptances (PDF)	1-2%				X
Luminosity	2.6%		X	X	X
Lepton selection efficiency	1-2%		X	X	X
Lepton trigger efficiency	1%		X	X	X
Signal shape (interference)	See Fig. 5				X

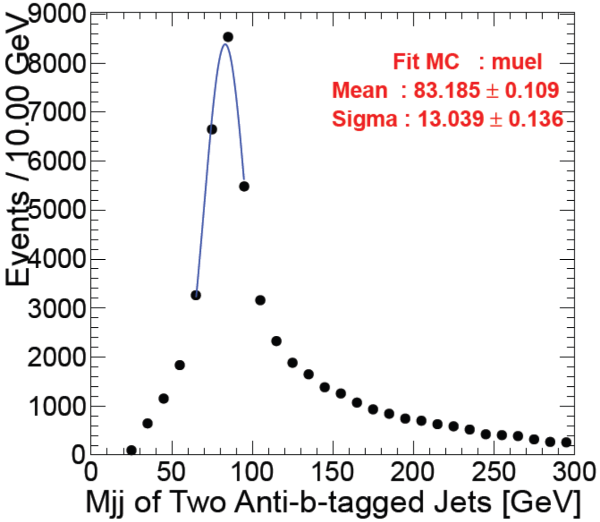
- **MVA selection efficiency uncertainty: 10% a safe, uniform systematic.**
- **Lepton efficiency uncertainties: 2%.**
- **Trigger efficiency uncertainty: 1%**
- **Signal cross-section uncertainties: taken from YRv3.**
- **PDF variations: a few %.**
- **LHC luminosity: 2.6%.**
- **Interference for masses from 400 GeV and up**
    - **shape and normalization uncertainty.**



CMS preliminary 2012 ∫ L dt = 19.3 fb-1 √s = 8 TeV
WZ
WW
DY Jets
TTbar
W Jets
Events / 10.00 GeV
Mjj of Two Anti-b-tagged Jets [GeV]



Fit Data : muel
Mean : 84.061 ± 0.149
Sigma : 14.080 ± 0.188
Events / 10.00 GeV
Mjj of Two Anti-b-tagged Jets [GeV]

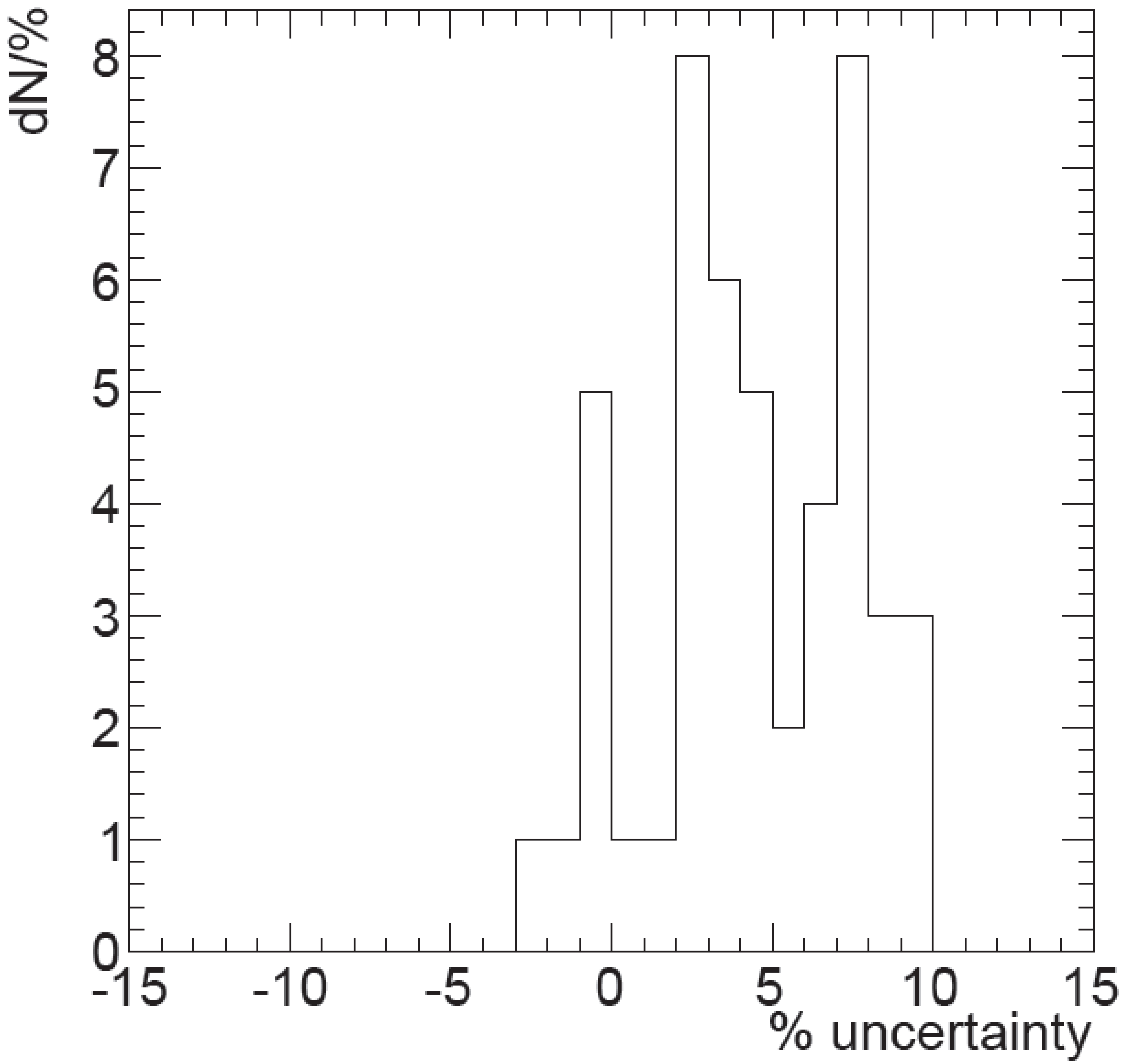


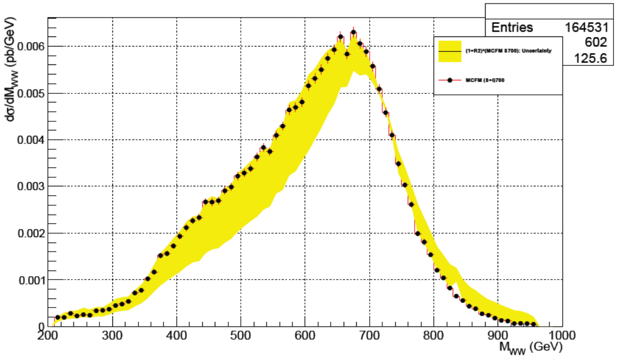
Fit MC : muel
Mean : 83.185 ± 0.109
Sigma : 13.039 ± 0.136
Events / 10.00 GeV
Mjj of Two Anti-b-tagged Jets [GeV]

Four body mass range

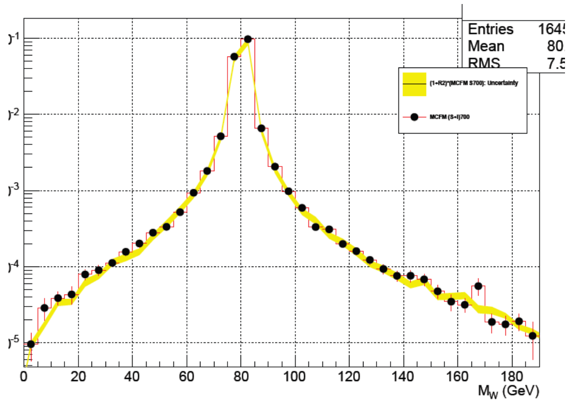
mass	lower limit (GeV)	upper limit (GeV)	N bins
170	165	245	100
180	165	245	100
190	165	245	100
200	165	245	100
250	200	400	100
300	220	400	90
350	250	475	90
400	300	600	100
450	380	900	130
500	420	900	120
550	420	900	120
600	420	900	120

Uncertainty on signal selection efficiency

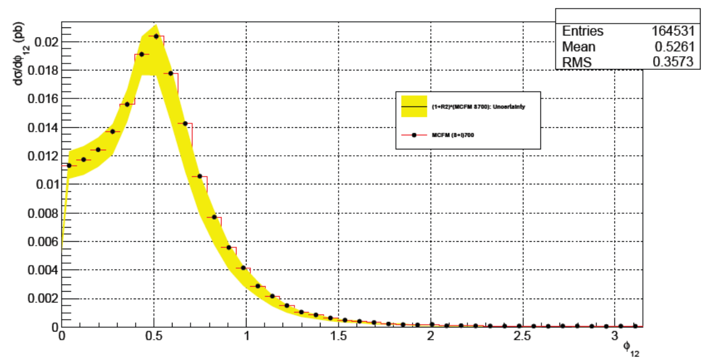




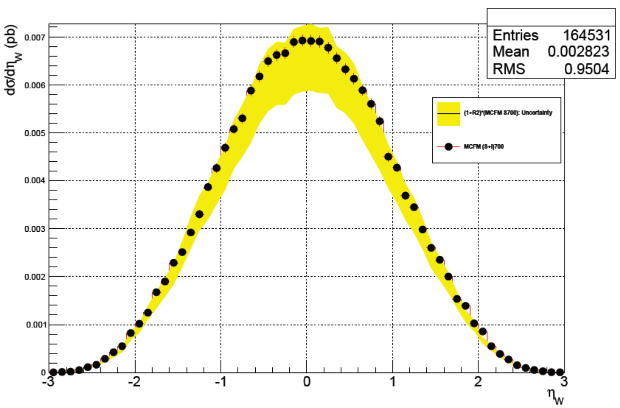
(a) M_{WW}



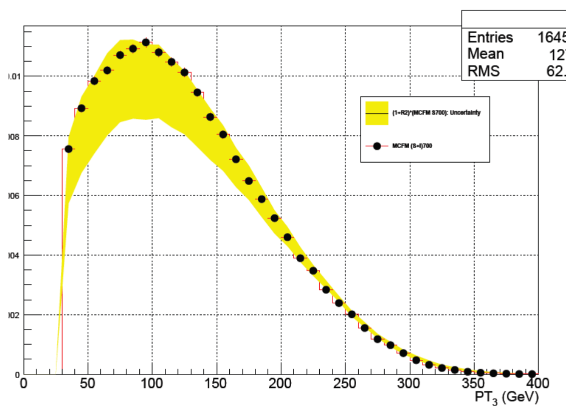
(b) $M_{l\nu}$



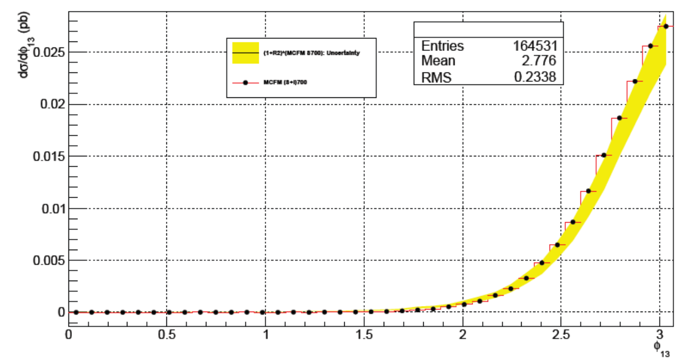
(e) $\phi_{l,\nu}$



(c) $\eta_{l\nu}$

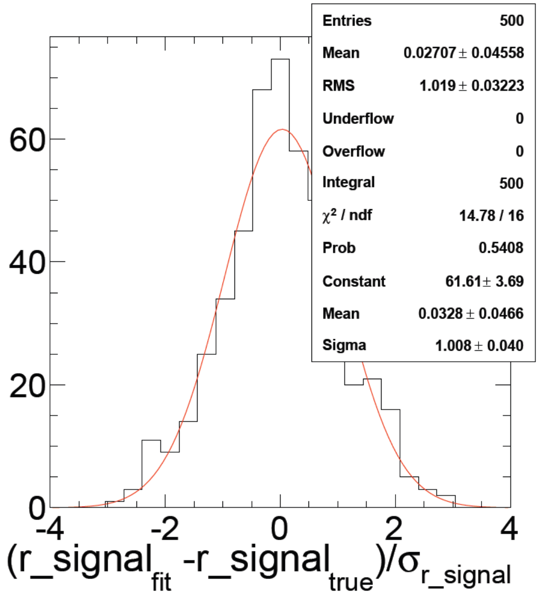


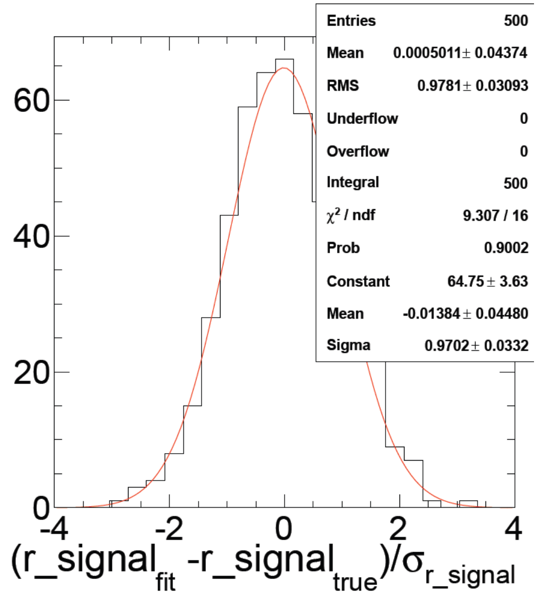
(d) $P_{T,l}$

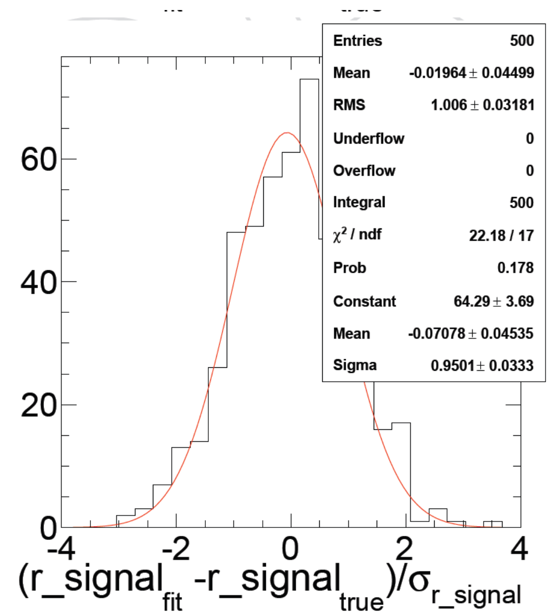


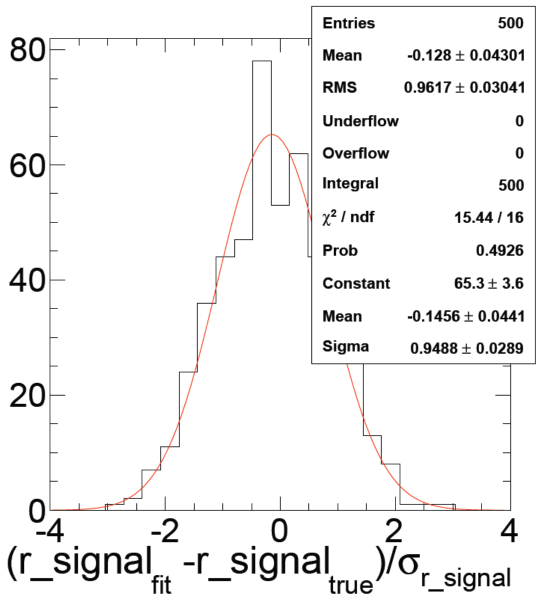
(f) $\phi_{l,j}$

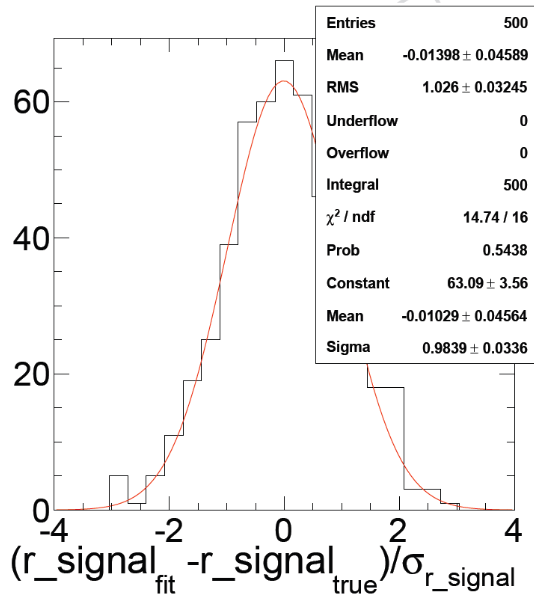
Pull distribution under the 0.5 signal generation

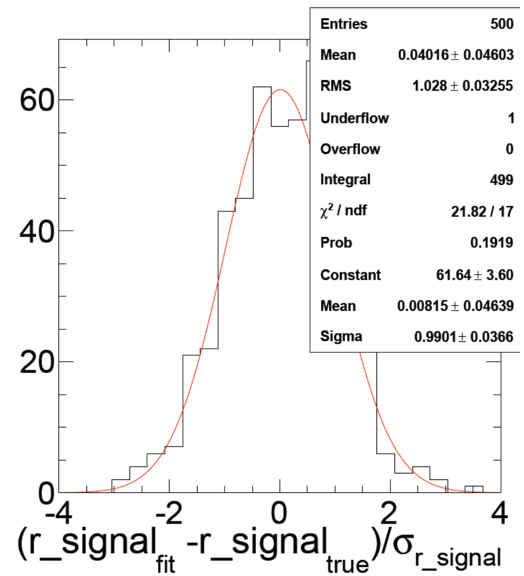




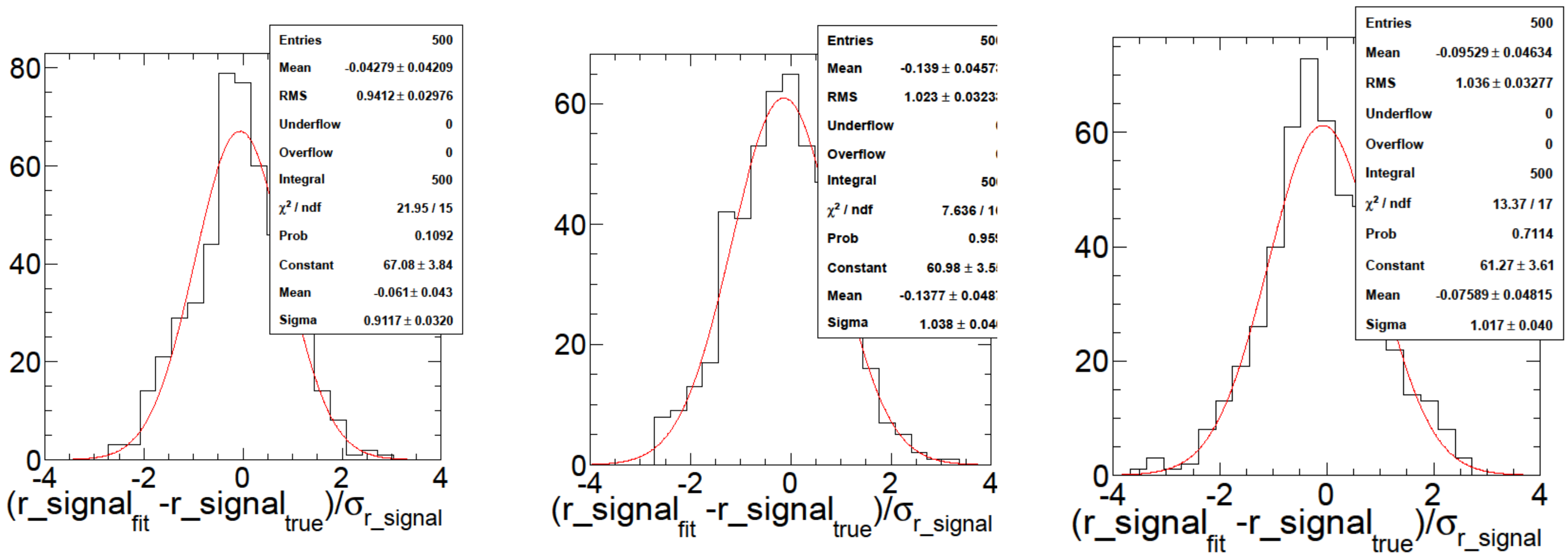








Pull for mass point 170GeV for 0, 0.5 & 1.0 times SM for the amount of higgs signal included in each pseudo –data experiment.



BSM interpretation

- Search for electroweak singlet scalar where a heavy higgs boson mixes with higgs at 126GeV .

- Couplings related by unitarity so,
- If C(C′) scale factor of couplings of low(high) mass higgs w.r.t. SM ,

$C^2 + C'^2 = 1$

- Indirectly can set upper limit at 95% CL on C'^2 <0.446 using signal strength fits to the H(126) Candidate.

- The heavy higgs σ modified by a factor μ' and modified width is Γ'

$\mu' = C'^2 \; (1 - BR_{new})$, $\Gamma' = \Gamma_{SM} \times C'^2 / (1 - BR_{new})$

BR_{new} is the branching ratio of heavy higgs to non-SM like decay modes.

BSM implementation

- The BSM heavy higgs line shape by reweighting the SM POWHEG samples.
- Rescaling of the SM at NLO in QCD and LO in EWK.
- Set a target line shape a realistic Breit-Wigner with a narrower signal width w.r.t. width of SM higgs boson.
- Interference between the BSM Higgs and the background :

$$(\mu + I)_{BSM} = \mu_{SM} \; C'^{2} + I_{SM} \; C'$$

$\mu(I)$: signal strength (interference) in the BSM and SM cases.

This assumption is based on the hypothesis that the couplings are similar to the SM case and simply re-scaled due to unitarily constraints.

BSM limits

BRnew = 0.0 0.1 0.2 0.3 0.4 0.5

C′ = 0.1

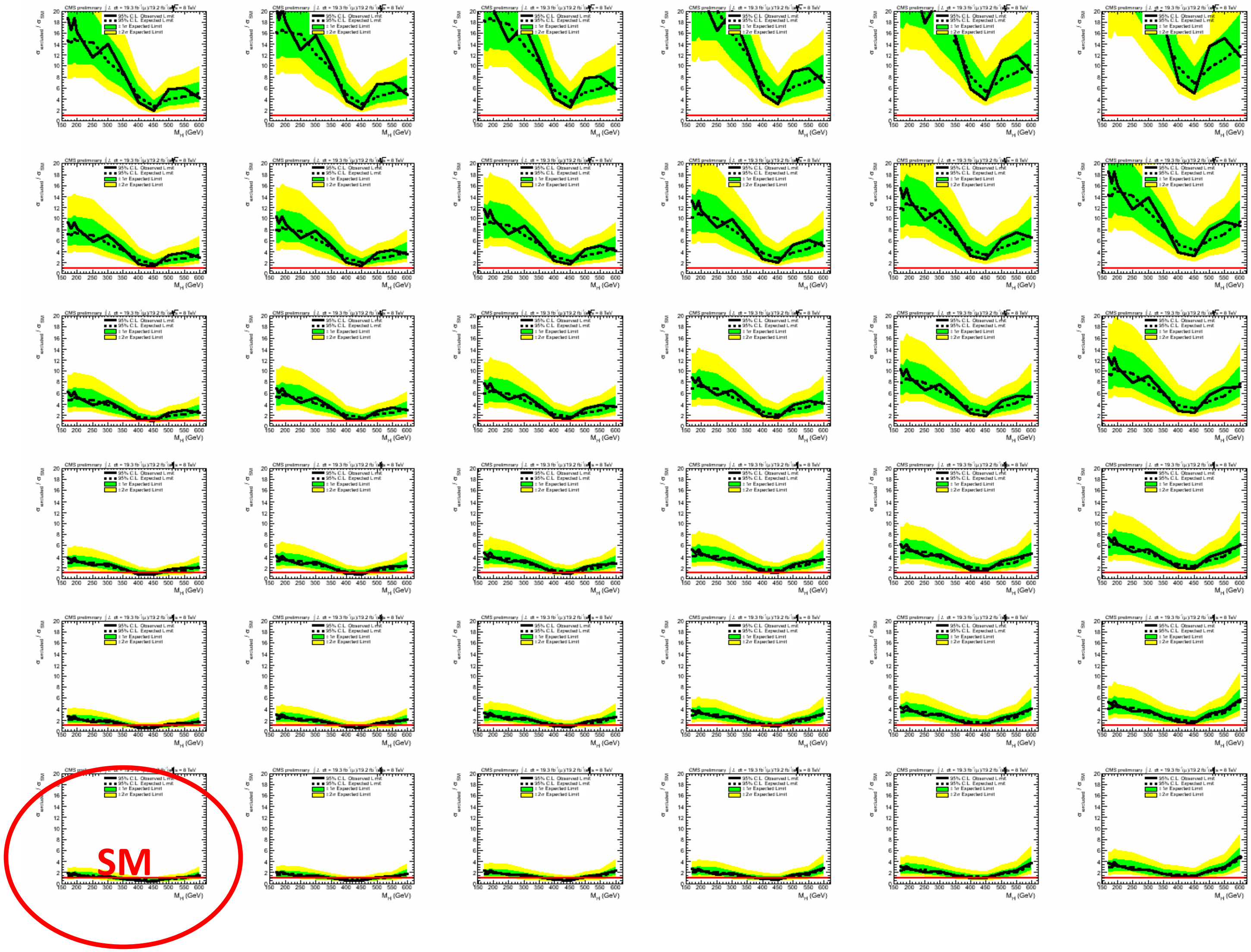
C′ = 0.2

C′ = 0.3

C′ = 0.5

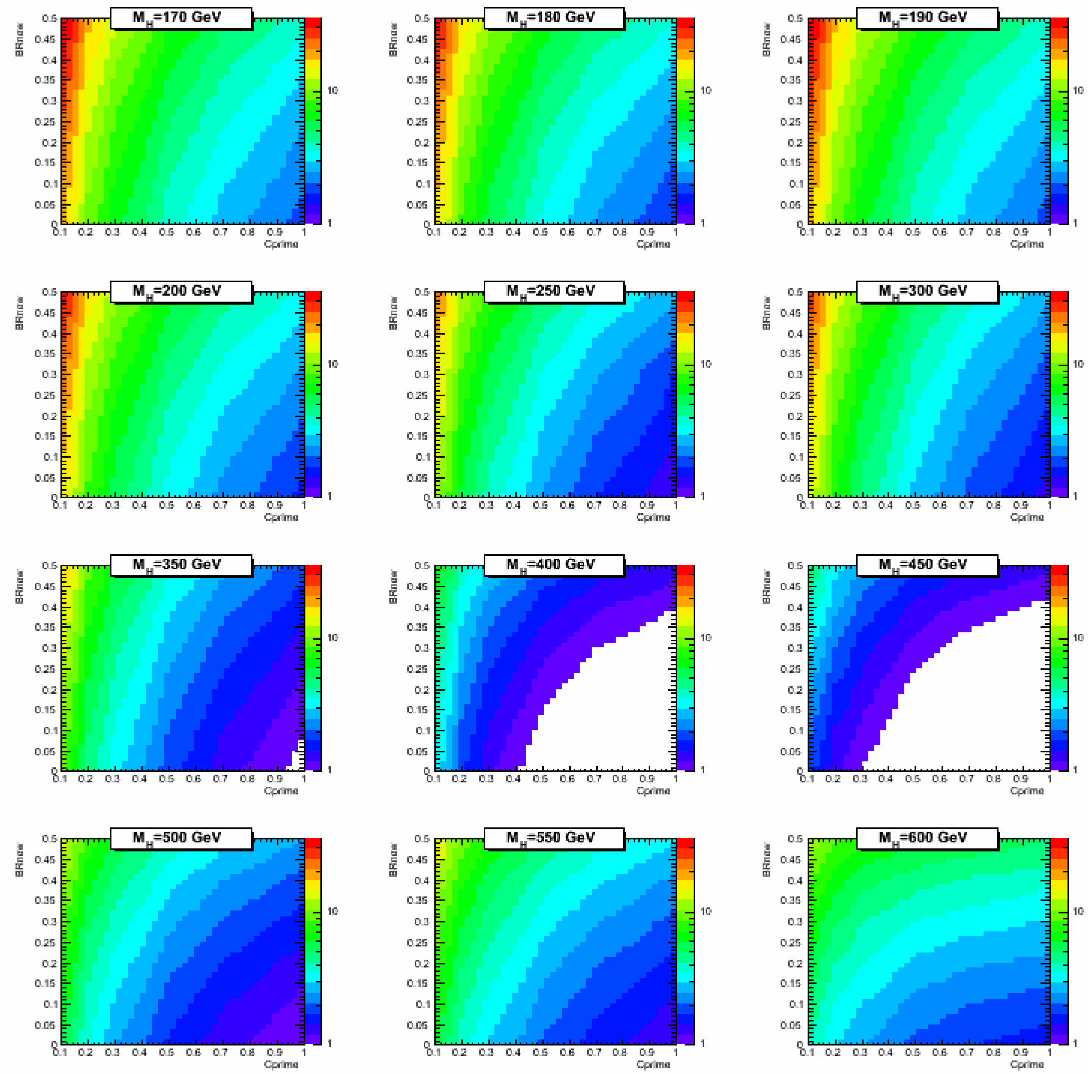
C′ = 0.7

C′ = 1.0

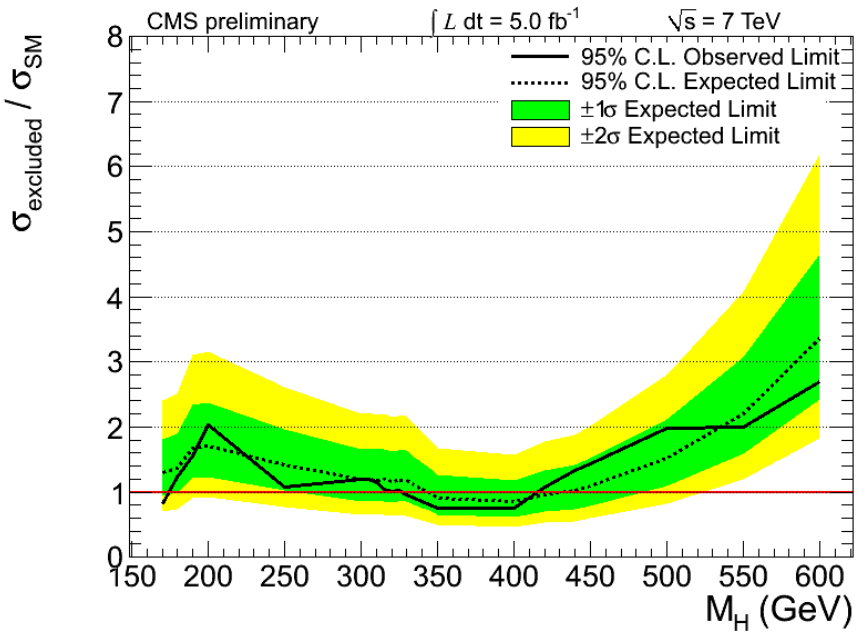


BSM limits

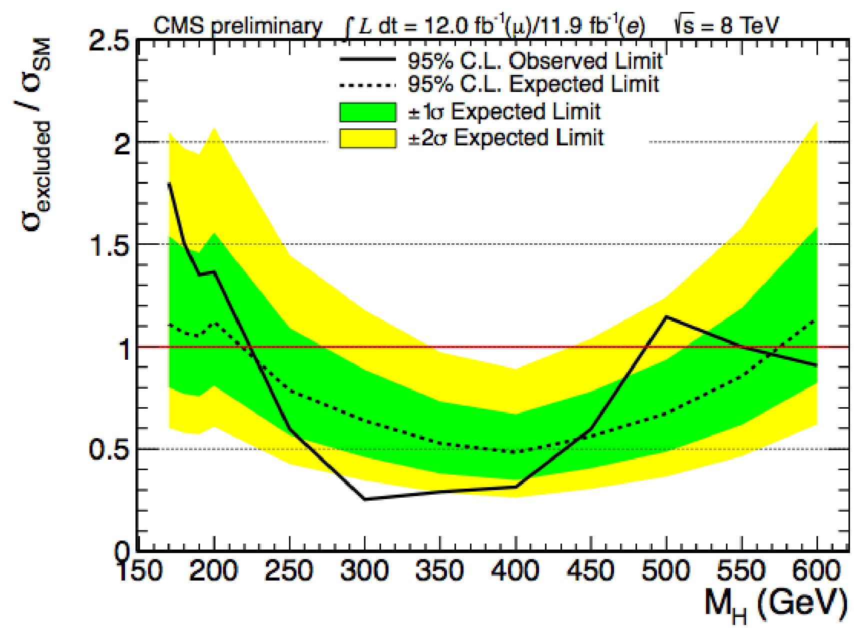
- An exercise in visualization…
- Plot **observed** excluded signal strength in the C′ / BRnew space
- **Lower right corner is equivalent to the SM,** white indicates exclusion
- 8 TeV only data



History



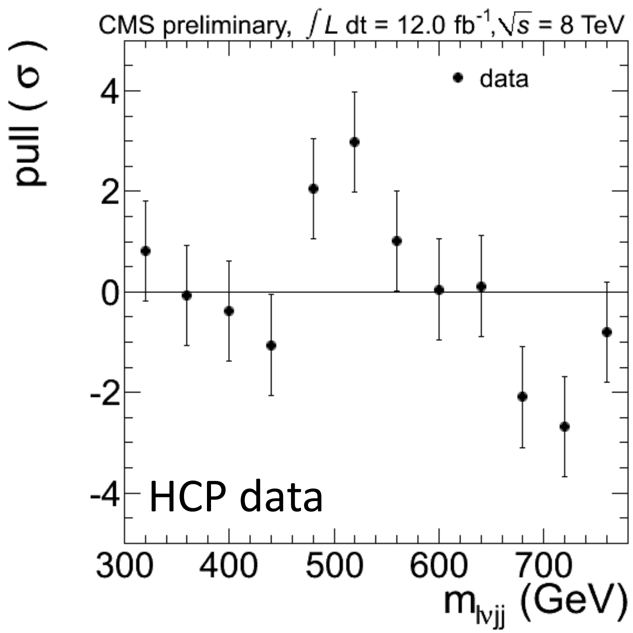
7 TeV only (HIG-12-003)

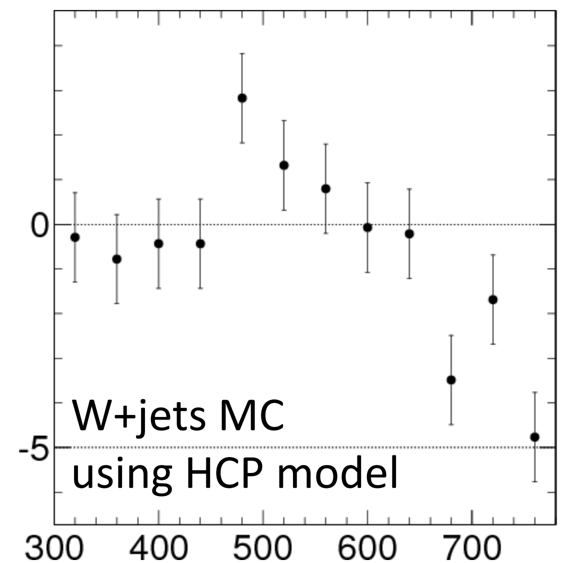


Last public result in this channel was for HCP 2012, HIG-12-046

More History

- The previous analysis used data from the sidebands in the m_{jj} distribution to determine the normalization and shape for the $m_{\ell\nu jj}$ distribution of the W+jets background in the m_{jj} signal window.
  - This relied on the MC to make the shape extrapolation.
  - At the time of HCP, the statistics were already such that this description was being stretched.
  - The full dataset would need a better background description.





Validation 0x SM